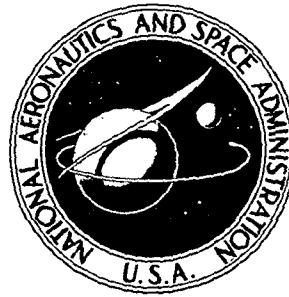


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**SUPERSONIC AERODYNAMIC
CHARACTERISTICS OF A MODEL
OF AN AIR-TO-GROUND MISSILE**

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUPERSONIC AERODYNAMIC CHARACTERISTICS OF A MODEL OF AN AIR-TO-GROUND MISSILE

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SUMMARY

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An investigation has been conducted to determine the aerodynamic characteristics of a model of an air-to-ground missile simulating both the boost- and glide-phase configurations. The results include the effects of fin size and sweep angle as well as the effects of the size and deflection of the control wings. The investigation was conducted for model roll angles of 0° and 45° at Mach numbers of 1.60 and 2.00 at a Reynolds number of 8.41×10^6 based on the body length.

The results of the investigation indicated that the body-fin combination was generally stable about the assumed moment center for the range of fin size and fin sweep angle of the tests, although at Mach number 2.00 and at a sweep angle of 65° , regions of instability were indicated for angles of attack above about 9° . The addition of the control wings had little effect on the longitudinal stability but did produce a substantial increase in normal-force curve slope and in axial force. Deflection of the control wings was effective in providing increments of side force and normal force with essentially no effect on pitching or yawing moments. The presence of wing slots, which simulated slots into which the wings fold, had no effect on the aerodynamic characteristics of the model.

INTRODUCTION

Tests have been conducted to determine the aerodynamic characteristics of an air-to-ground missile configuration which employs a simple bang-bang type of control wing, located near the midbody, for control during the guided phase. During boost, the control wings are retracted and the aft stabilizing fins are partially extended and have a sweep angle of 65° . After boost the control wings are extended and the fin sweep angle is reduced to 30° . During the guided phase it is necessary that the control wings provide the required control without producing large pitch or yaw angles, since the missile has aft-directed guidance beam sensors.

A wind-tunnel investigation was made to determine the effects of fin size and sweep angle as well as the effects of control wing size and wing deflection on both the lateral-directional and the longitudinal aerodynamic characteristics. The model consisted of a

cylindrical body with an ogive nose, and two sets of cruciform fins. Provisions were made so that variations could be made in the deflection angle of the control wings, in the leading-edge sweep angle of the stabilizing fins, and in the span of the wings and fins.

The investigation was conducted at Mach numbers of 1.60 and 2.00 at angles of attack from about -6° to 10° with an angle of sideslip of 0° . The Reynolds number based on the body length was 8.41×10^6 at both Mach numbers.

SYMBOLS

The force and moment data are presented in coefficient form referred to the body-axis system with the moment reference center located on the model center line at a point 52.0 percent of the body length aft of the model nose.

| | |
|----------|---|
| A | cross-sectional area of body |
| C_A | axial-force coefficient, $\frac{\text{Axial force}}{qA}$ |
| C_m | pitching-moment coefficient, $\frac{\text{Pitching moment}}{qAd}$ |
| C_N | normal-force coefficient, $\frac{\text{Normal force}}{qA}$ |
| C_l | rolling-moment coefficient, $\frac{\text{Rolling moment}}{qAd}$ |
| C_n | yawing-moment coefficient, $\frac{\text{Yawing moment}}{qAd}$ |
| C_Y | side-force coefficient, $\frac{\text{Side force}}{qA}$ |
| d | body diameter |
| M | Mach number |
| q | free-stream dynamic pressure |
| α | angle of attack, deg |

| | |
|------------|---|
| δ_h | deflection angle of horizontal control wings, positive with trailing edge down, deg |
| δ_v | deflection angle of vertical control wings, positive with trailing edge left, deg |
| Λ | sweep angle of stabilizing fins, deg |
| ϕ | roll angle of model, deg |

APPARATUS AND METHODS

Model and Support System

Details of the model are presented in figure 1. The model is shown in a $\phi = 0^\circ$ attitude. The model consisted of a cylindrical body and an ogive nose and had a fineness ratio of about 12.22. Four rectangular, cruciform wings were located at the moment reference center of the model. Provision was made for the horizontal wings to be set at 0° or -5° , and for the vertical wings to be set at 0° or 5° . In addition, the wings could be removed to simulate the wings-retracted condition. Slots through the body at the wing location simulated the openings into which the wings retracted. Plates were used to cover the slots to determine the effect of airflow through the slots. Four stabilizing tail fins were located near the base of the model and were interdigitated with the wing surfaces. Attachment to the body was such that the fins could be placed at sweep angles of either 30° or 65° . Two sets of control wings and stabilizing fins that differed only in span were used. Model component designations are as follows:

| | |
|----------------|-------------|
| B | body |
| F ₁ | small fins |
| F ₂ | large fins |
| W ₁ | small wings |
| W ₂ | large wings |

The model was attached to an internally mounted electrical strain-gage balance which was attached to a rear-mounted sting. The sting, in turn, was attached to the tunnel central support system which allowed remote control of the attitude of the model in the test section.

Tests and Corrections

The model was tested with the control wings in a vertical and horizontal position ($\phi = 0^\circ$) and also with the control wings in a 45° roll attitude ($\phi = 45^\circ$). The model was

considered to be in an upright position for both of these roll positions, that is, angle of attack and lift were always in a vertical plane in the wind tunnel. This arrangement essentially gives information on two different models, one of which stabilizes at $\phi = 0^\circ$, the other at $\phi = 45^\circ$. The stabilizing fins were always oriented in an interdigitated position with respect to the control wings.

Tests were made in the low Mach number test section of the Langley Unitary Plan wind tunnel through a range of angle of attack from about -6° to 10° , at an angle of sideslip of 0° , and at Mach numbers of 1.60 and 2.00. The free-stream stagnation temperature was maintained at 150° F (339° K). A constant Reynolds number of 8.41×10^6 based on the model length was maintained at both Mach numbers. The stagnation dewpoint was maintained at -30° F (239° K) in order to avoid condensation effects. The results have been corrected for tunnel flow angularity and deflection of the sting and balance under aerodynamic load. The balance chamber pressure was measured and the axial force was adjusted to a condition of free-stream static pressure at the model base.

RESULTS AND DISCUSSION

The effect of the size and sweep angle of the stabilizing fin on the longitudinal aerodynamic characteristics of the configuration with the control wings retracted is shown in figure 2. Increased longitudinal stability resulted from either increased fin size or decreased sweep or both. At $M = 1.60$, all configurations were stable about the assumed moment center. At $M = 2.00$, however, the stability level was reduced and the configuration with either size fin at $\Lambda = 65^\circ$ indicated regions of instability for angles of attack above about 9° . There was essentially no effect of roll angle on the longitudinal stability.

The effect of the control wings on the body-fin configurations is shown in figures 3 and 4 for the large surfaces and small surfaces, respectively. The addition of the control wings (fig. 3) produced a substantial increase in the normal-force curve slope and in the axial force, and a relatively small decrease in longitudinal stability. Deflection of the control wings resulted in essentially equal increments of normal and side force at $\phi = 0^\circ$ and had little effect on the longitudinal stability or on the pitching and yawing moments. At $\phi = 45^\circ$ the control wing orientation is such that all four controls are deflected to produce positive normal force. Thus, the increment in normal force is slightly larger than at $\phi = 0^\circ$ and the side force is unaffected. There is essentially no indication of any induced roll effects over the range of angle of attack of the tests.

The effect of the presence of slots, which simulated the cavities into which the wings fold, was determined by comparison of the aerodynamic characteristics with the

slots open and with the slots closed (fig. 5). The data show that there was essentially no effect of the slots on the aerodynamic characteristics of the model.

CONCLUSIONS

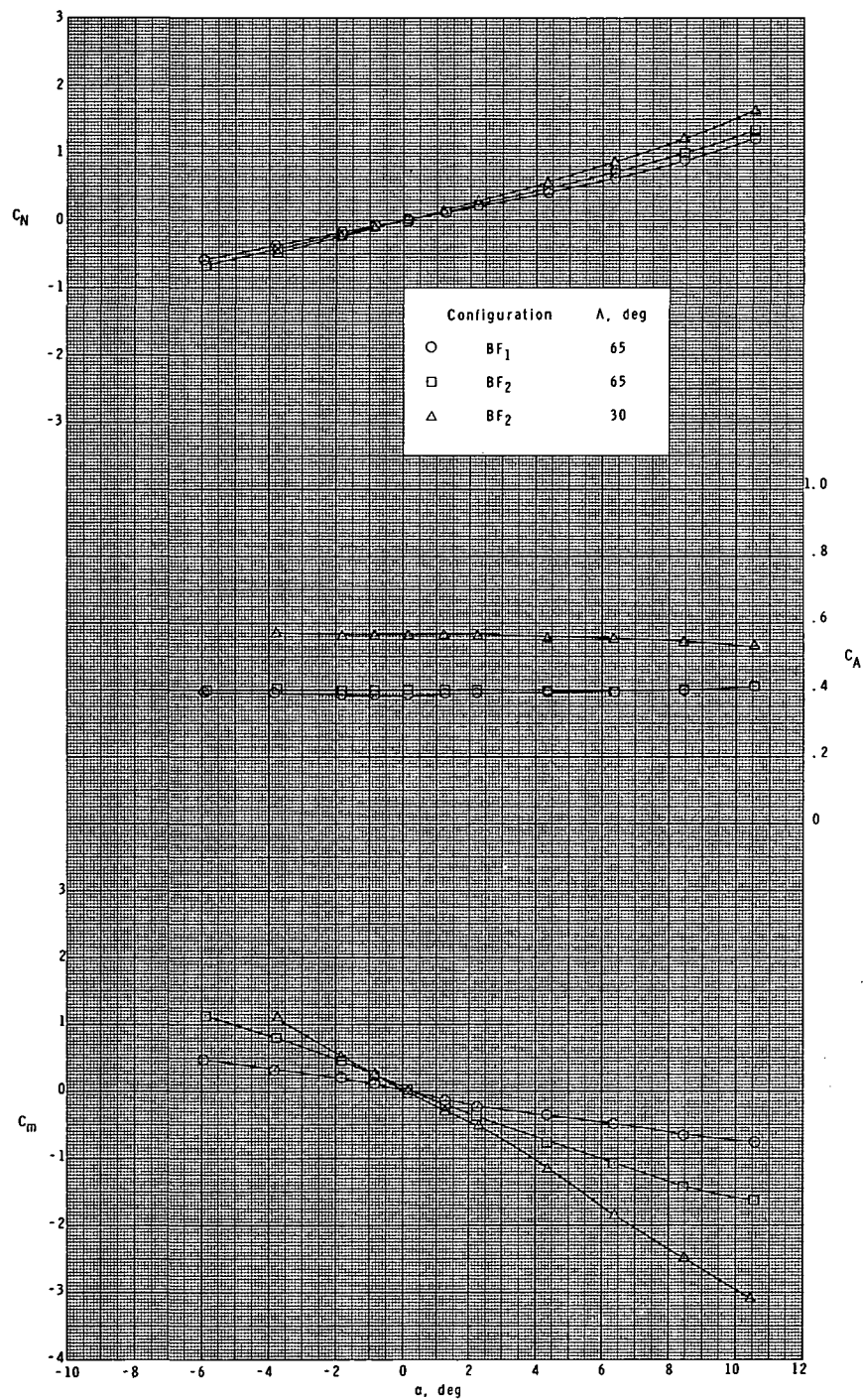
An investigation has been conducted to determine the aerodynamic characteristics of a model of an air-to-ground missile simulating both the boost- and glide-phase configurations. The results include the effects of fin size and sweep angle as well as the effects of the size and deflection of the control wings. The investigation was conducted for model roll angles of 0° and 45° at Mach numbers of 1.60 and 2.00 at a Reynolds number of 8.41×10^6 based on the body length. The results of the investigation indicated the following conclusions:

1. The body-fin combination was generally stable except for the 65° -swept fin at a Mach number of 2.00 where regions of instability were indicated above angles of attack of about 9° .
2. The addition of the control wings increased the normal-force curve slope and the axial force and had little effect on the stability characteristics.
3. Deflection of the control wings was effective in providing increments of side force and normal force with essentially no effect on yawing or pitching moments.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., August 16, 1967,
126-13-01-49-23.

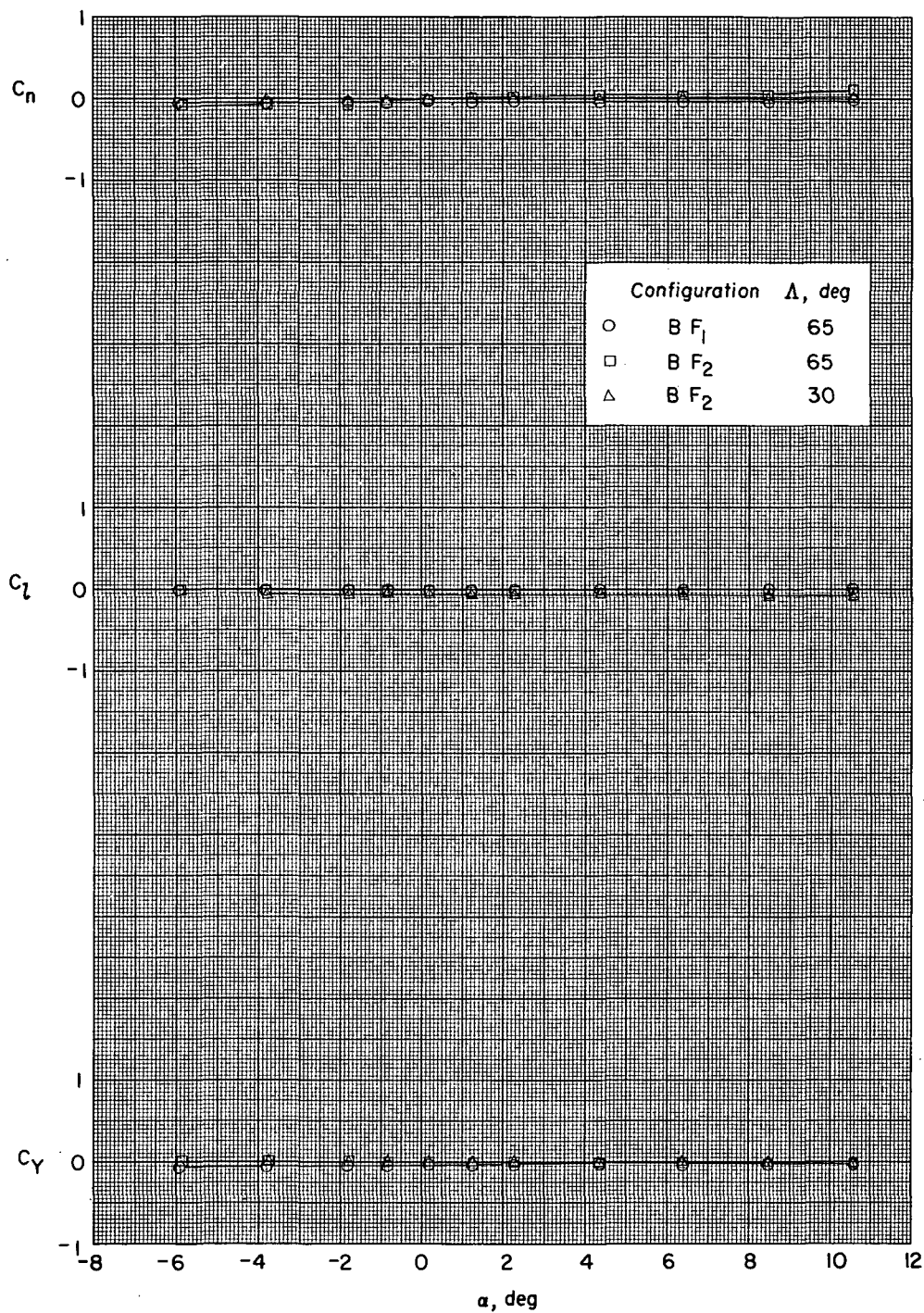
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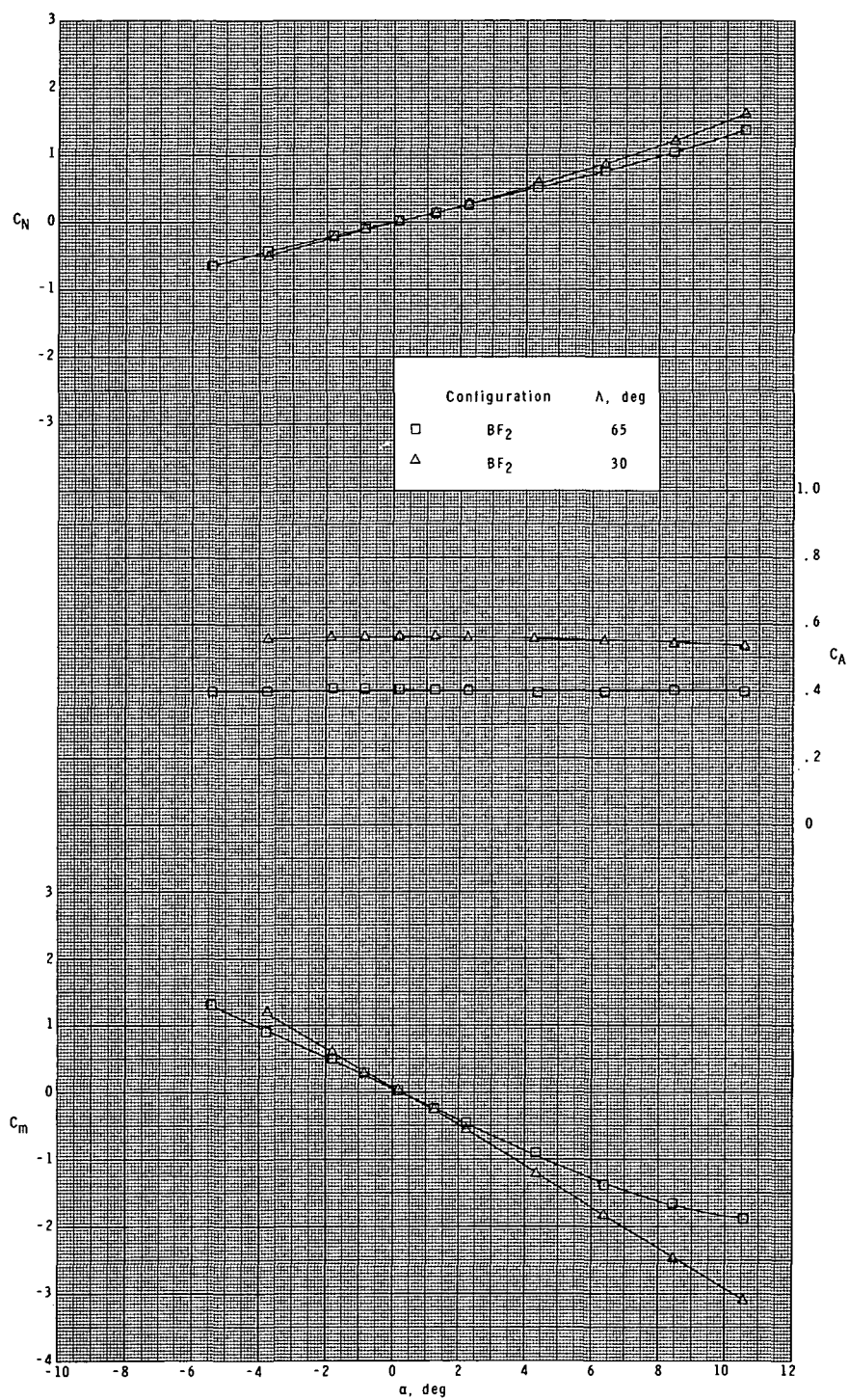
(a) Longitudinal aerodynamic characteristics. $M = 1.60$; $\Phi = 0^\circ$.

Figure 2.- Effect of fin size and sweep angle.



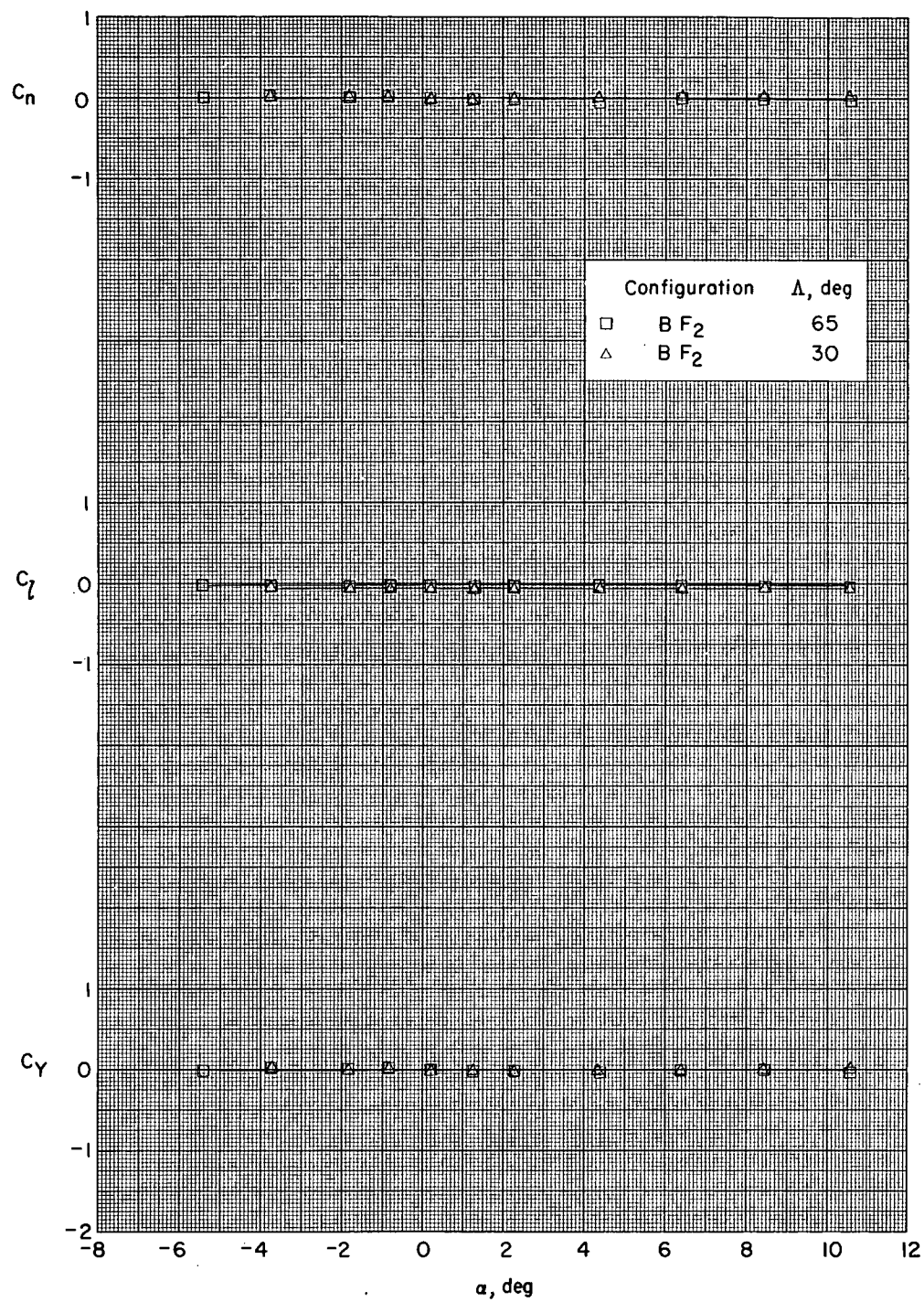
(b) Lateral-directional aerodynamic characteristics. $M = 1.60$; $\phi = 0^\circ$.

Figure 2.- Continued.



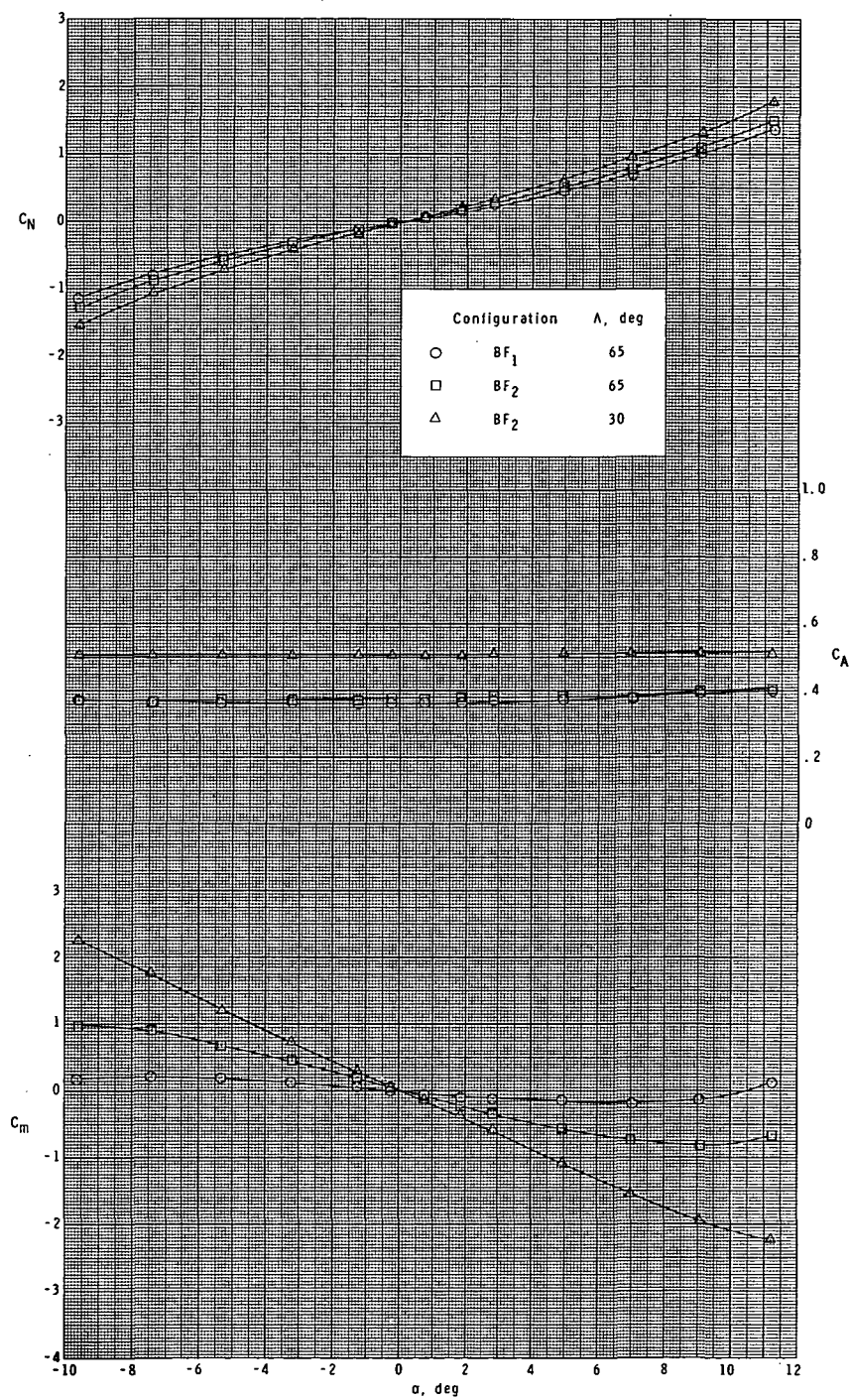
(c) Longitudinal aerodynamic characteristics. $M = 1.60$; $\phi = 45^\circ$.

Figure 2.- Continued.



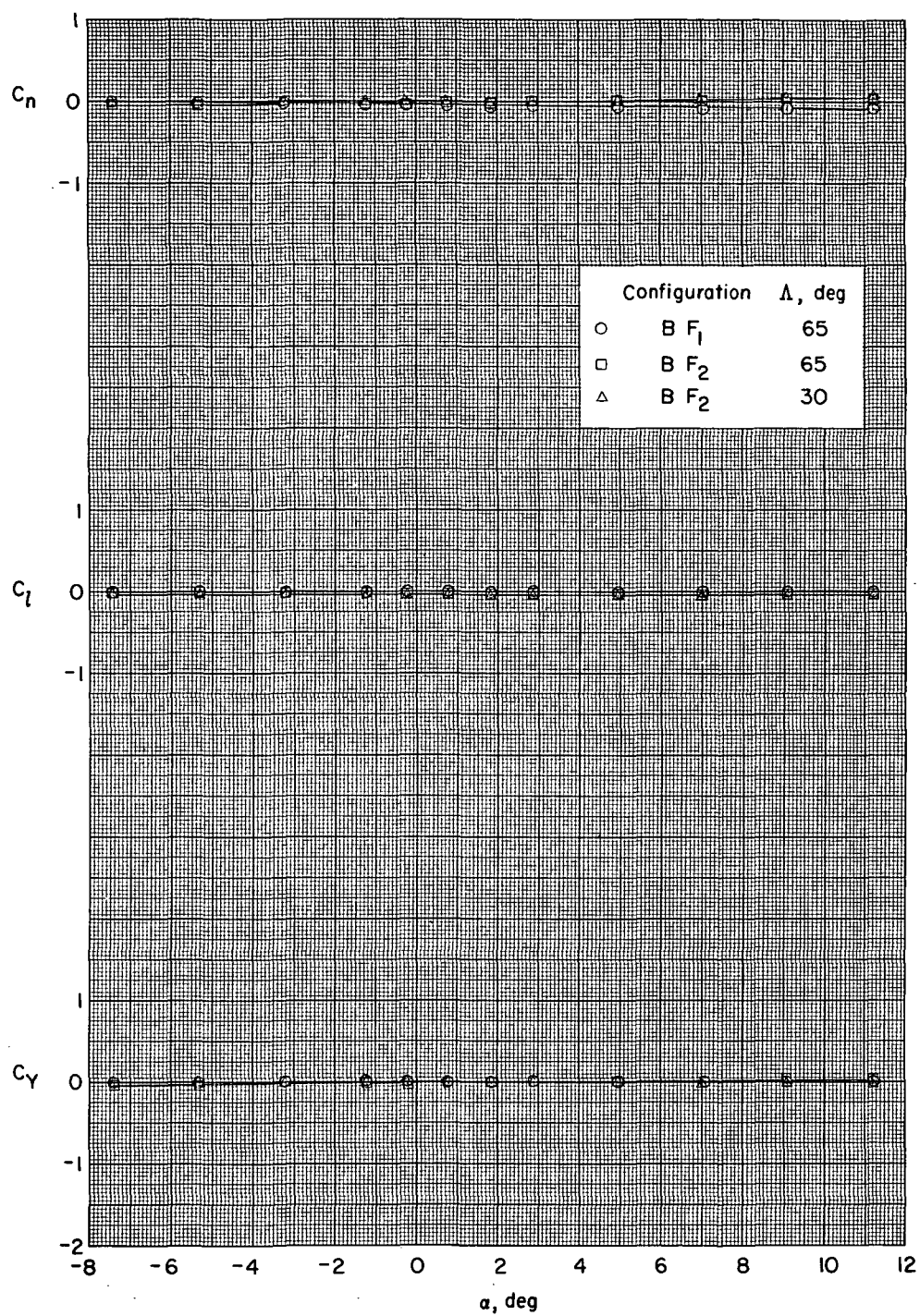
(d) Lateral-directional aerodynamic characteristics. $M = 1.60$; $\phi = 45^\circ$.

Figure 2.- Continued.



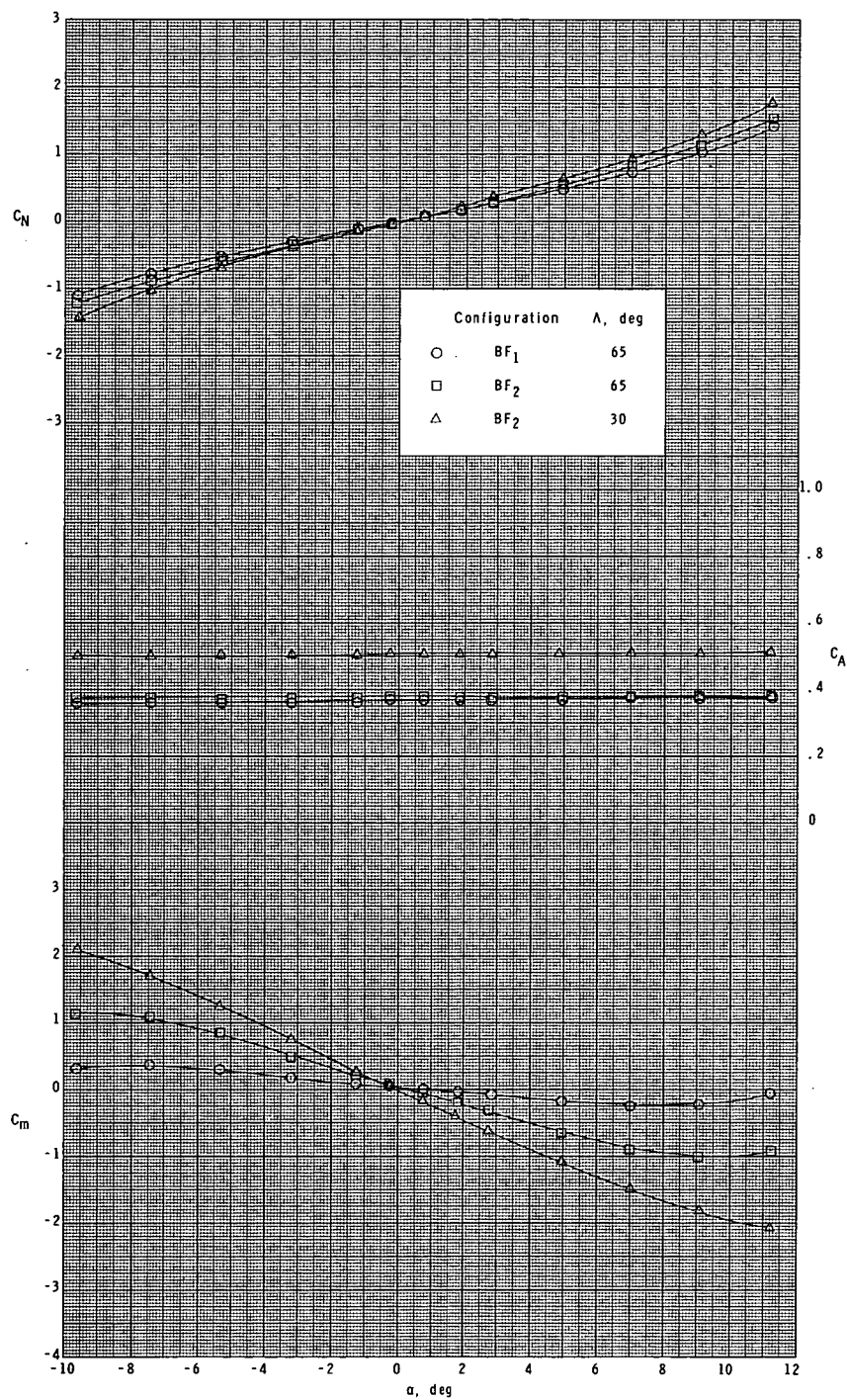
(e) Longitudinal aerodynamic characteristics. $M = 2.00$; $\phi = 0^\circ$.

Figure 2.- Continued.



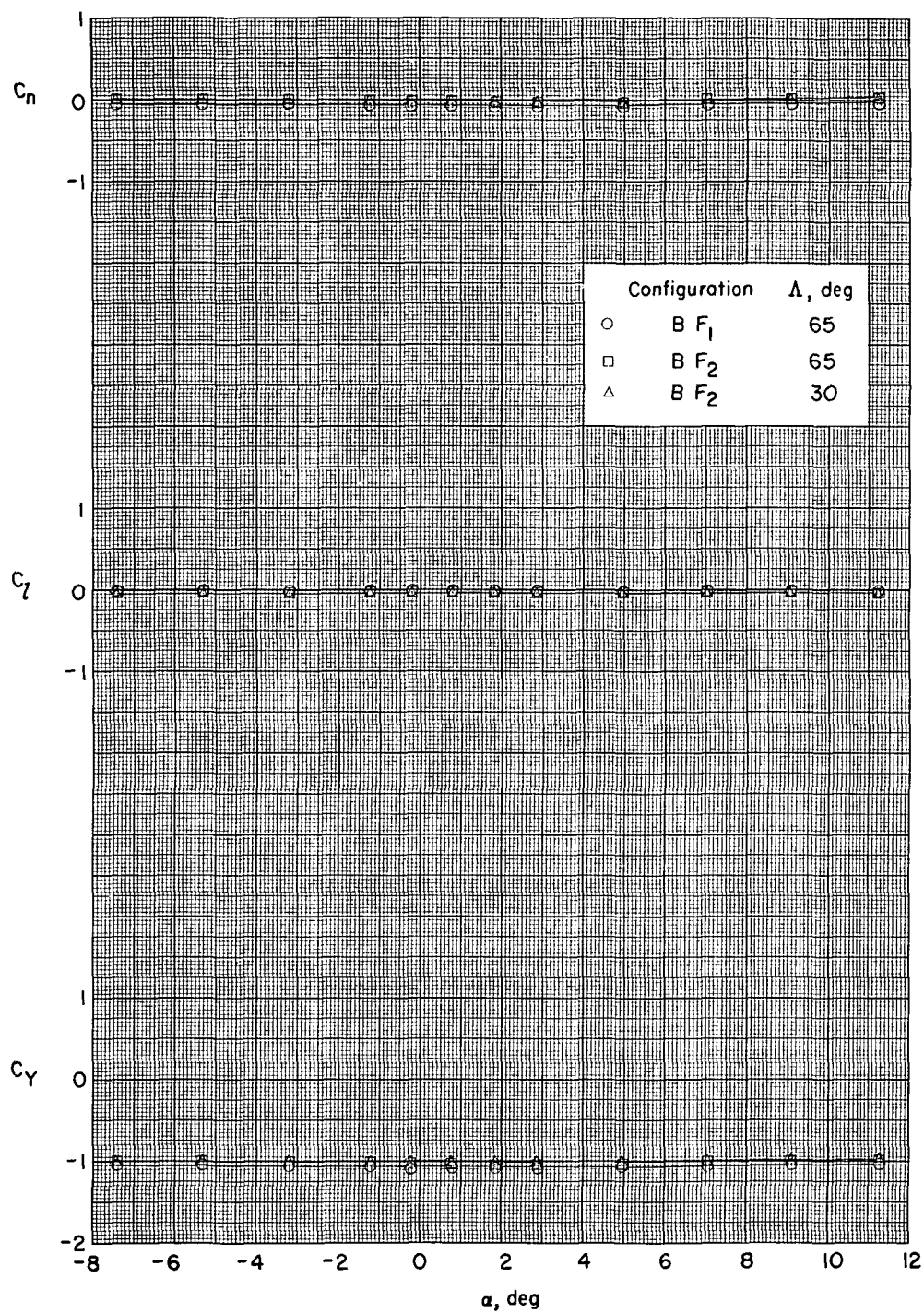
(f) Lateral-directional aerodynamic characteristics. $M = 2.00$; $\phi = 0^\circ$.

Figure 2.- Continued.



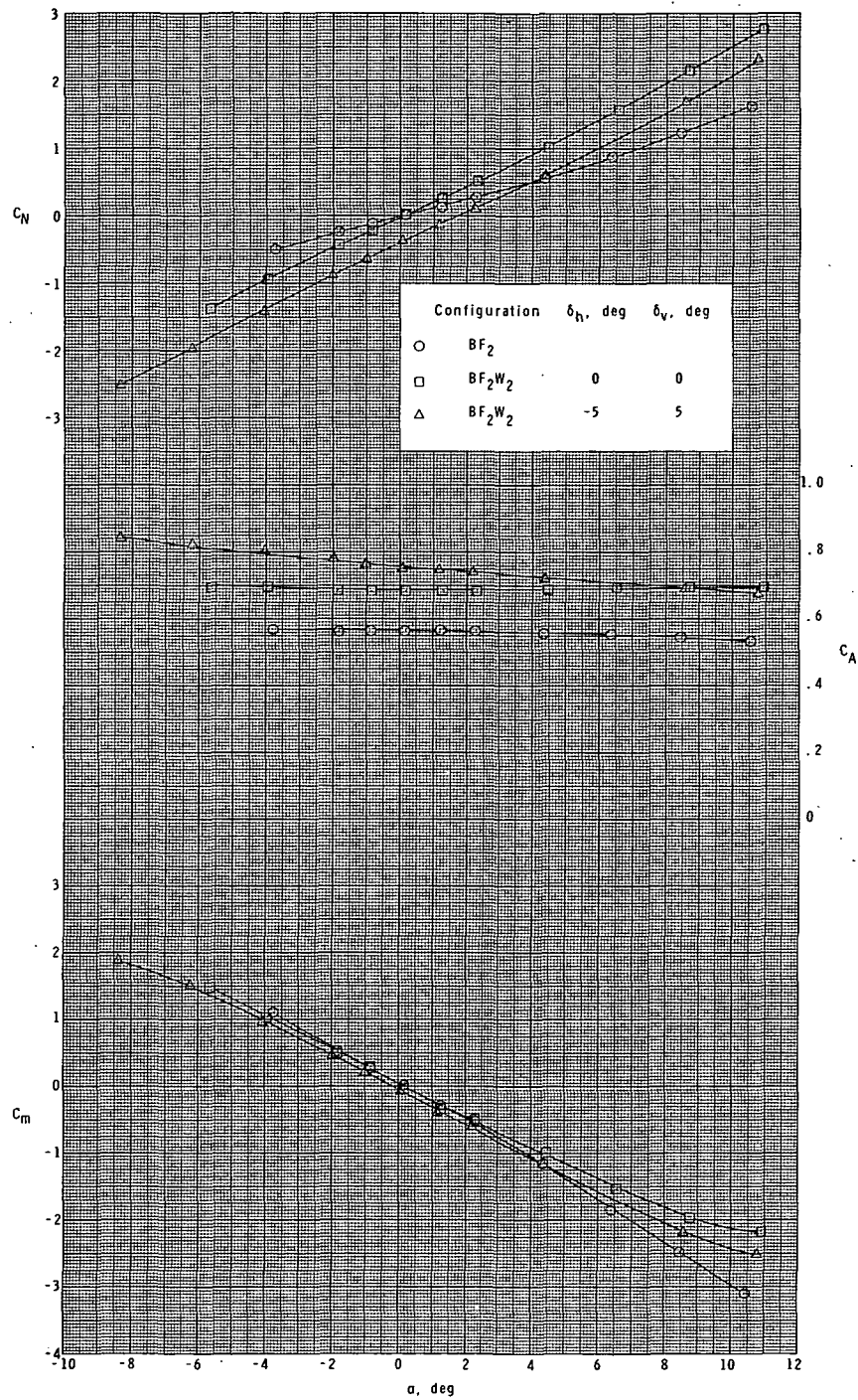
(g) Longitudinal aerodynamic characteristics. $M = 2.00$; $\Phi = 45^\circ$.

Figure 2.- Continued.



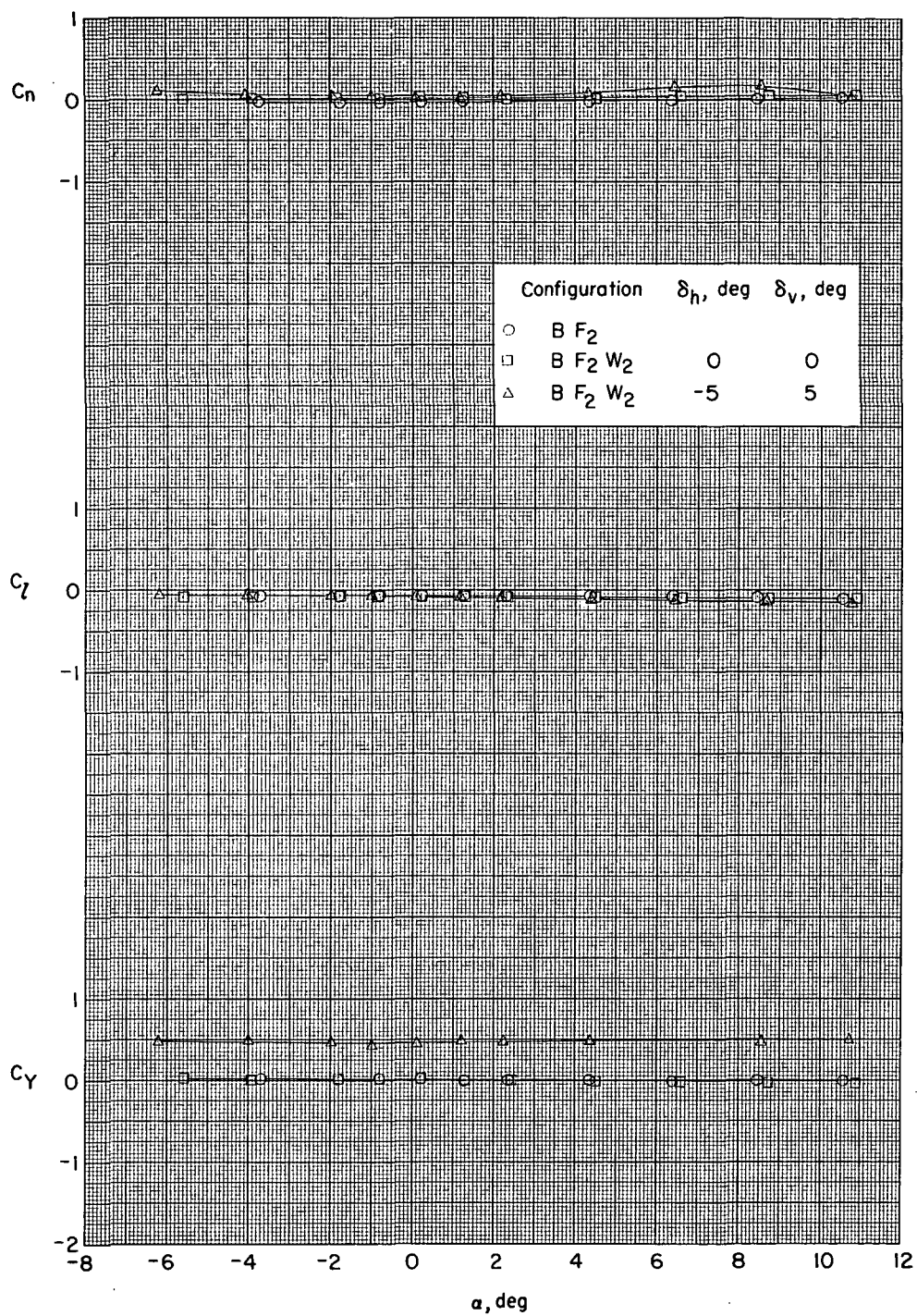
(h) Lateral-directional aerodynamic characteristics. $M = 2.00$; $\Phi = 45^\circ$.

Figure 2.- Concluded.



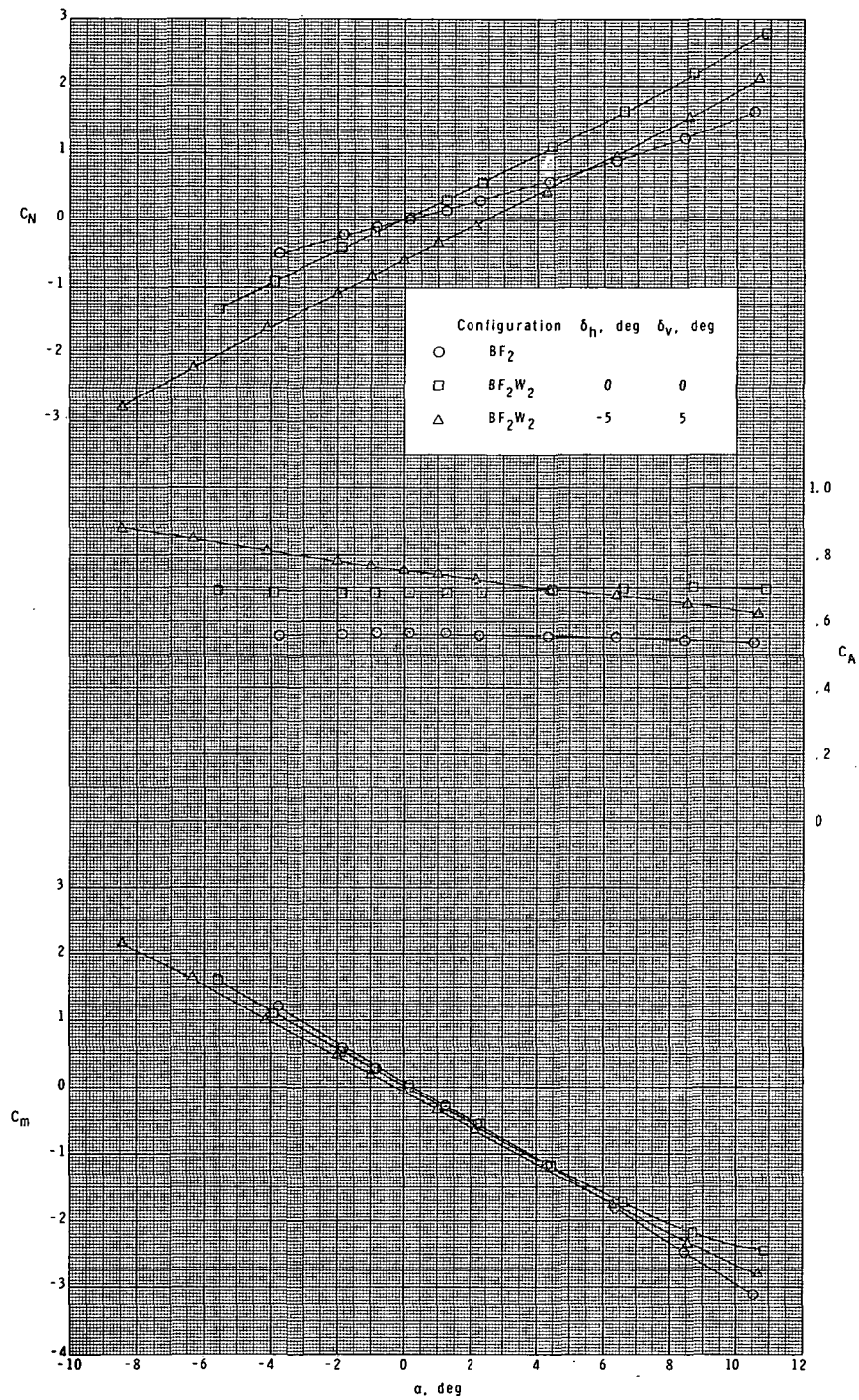
(a) Longitudinal aerodynamic characteristics. $M = 1.60$; $\Phi = 0^\circ$.

Figure 3.- Effect of control wings and control-wing deflection on the model with large wings and large fins.



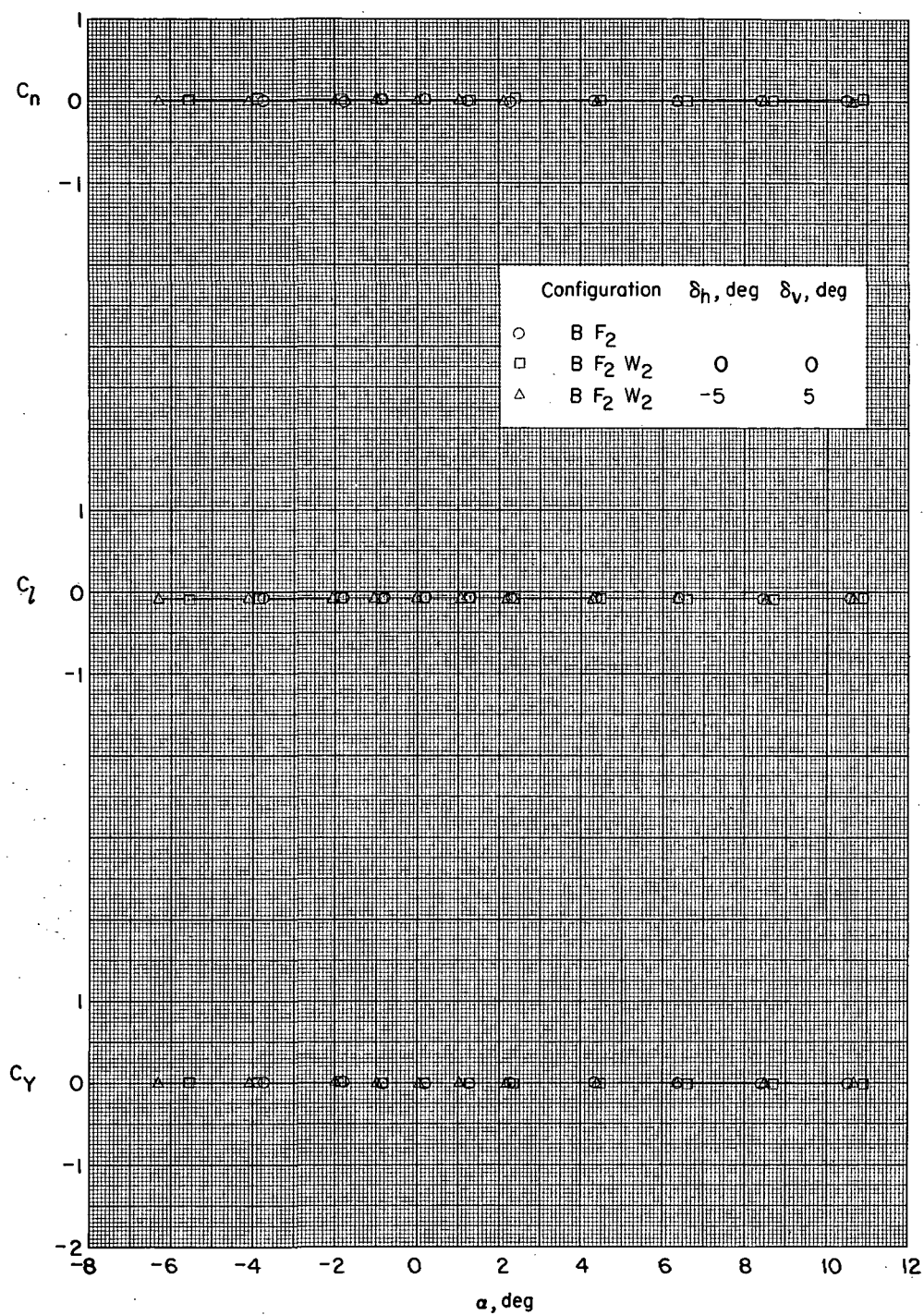
(b) Lateral-directional aerodynamic characteristics. $M = 1.60$; $\Phi = 0^\circ$.

Figure 3.- Continued.



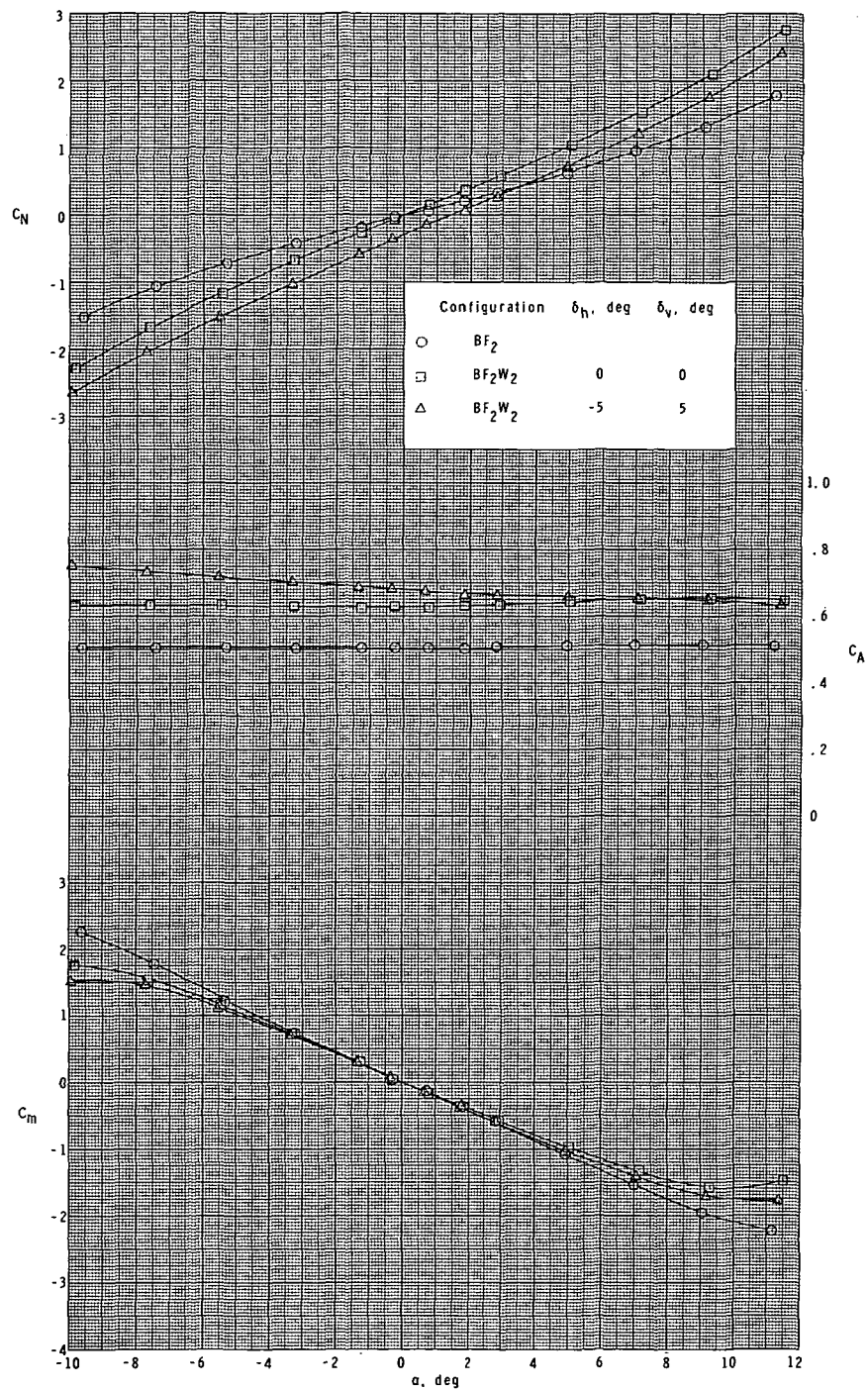
(c) Longitudinal aerodynamic characteristics. $M = 1.60$; $\Phi = 45^\circ$.

Figure 3.- Continued.



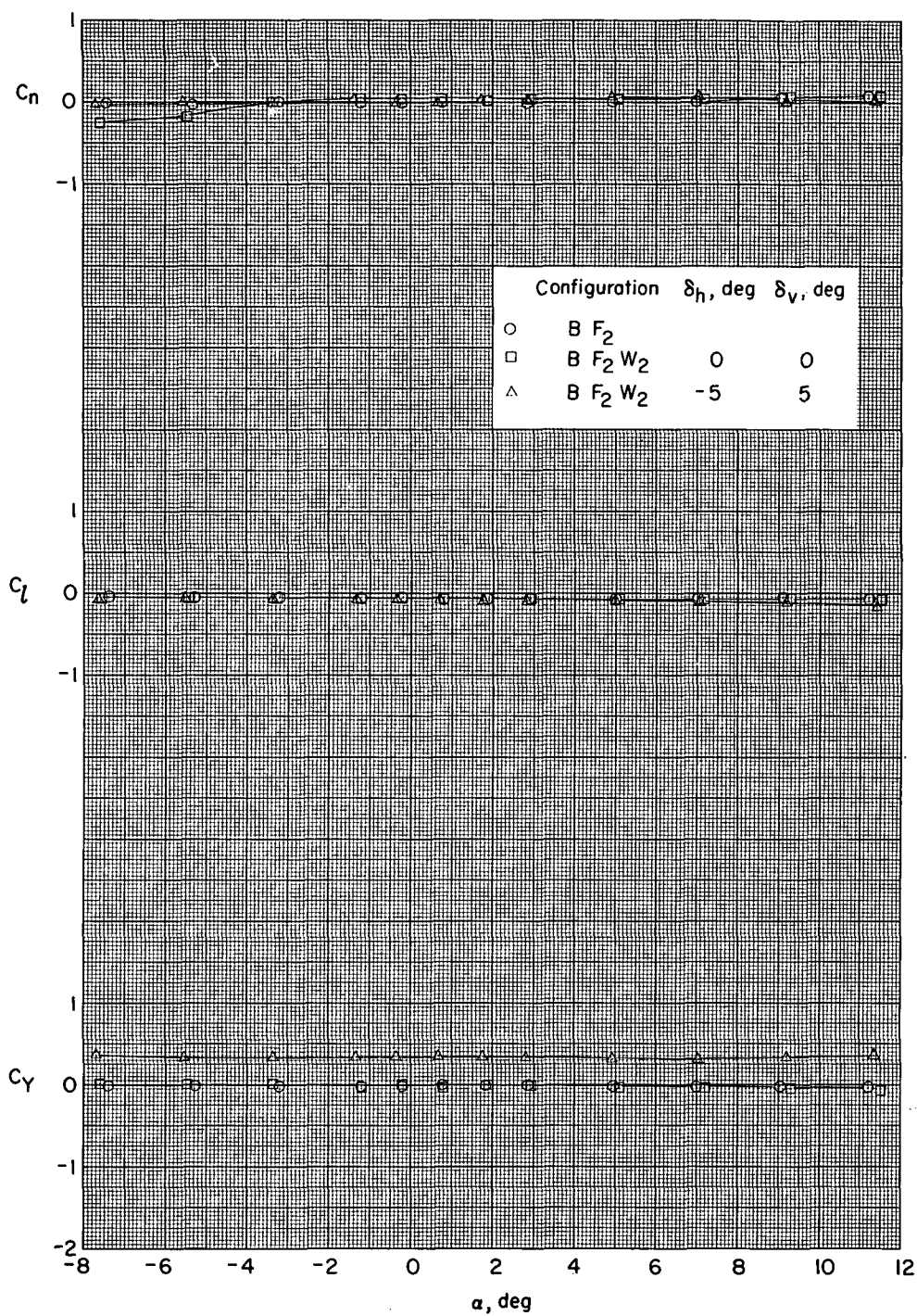
(d) Lateral-directional aerodynamic characteristics. $M = 1.60$; $\phi = 45^\circ$.

Figure 3.- Continued.



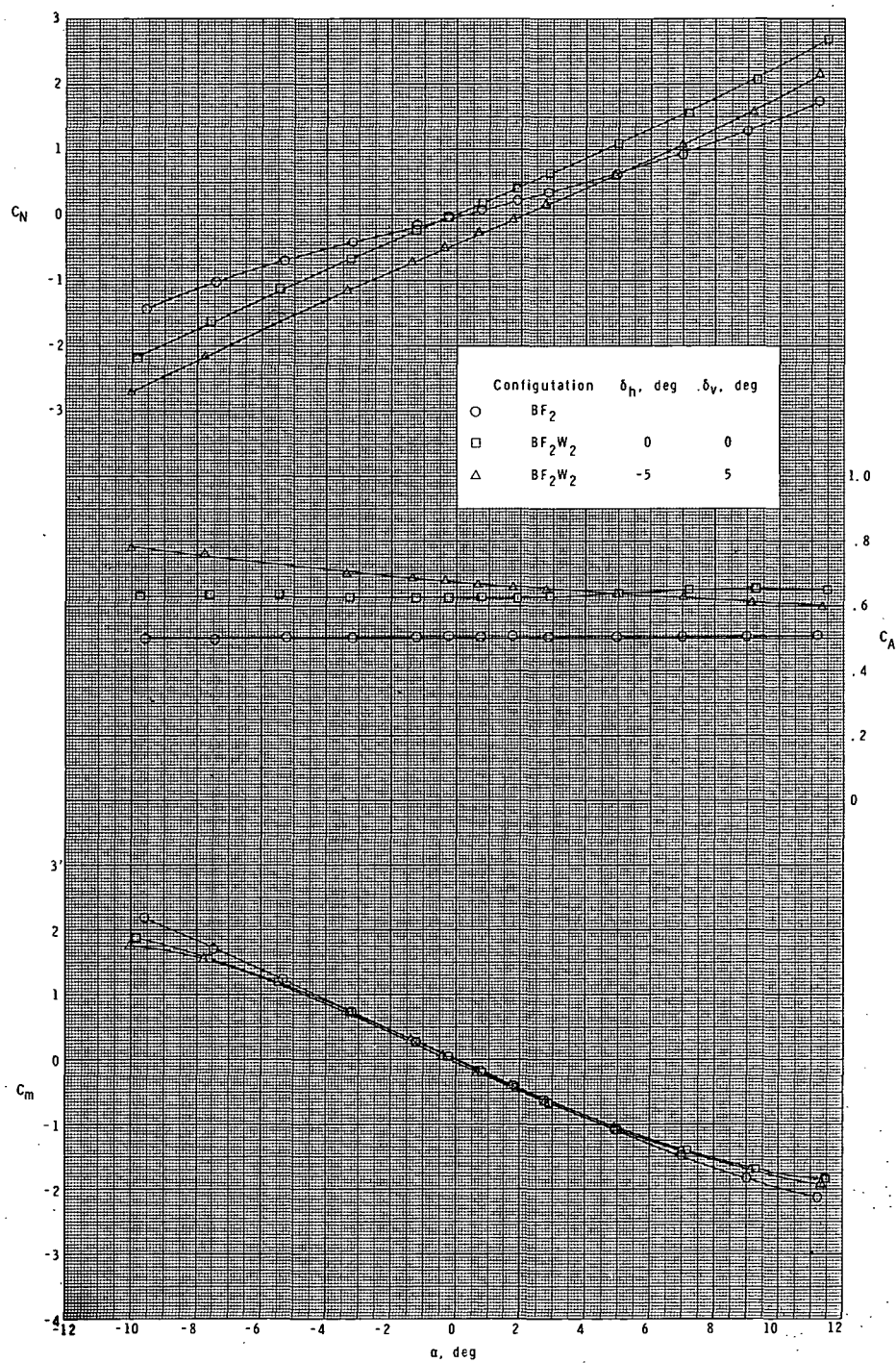
(e) Longitudinal aerodynamic characteristics. $M = 2.00$; $\phi = 0^\circ$.

Figure 3.- Continued.



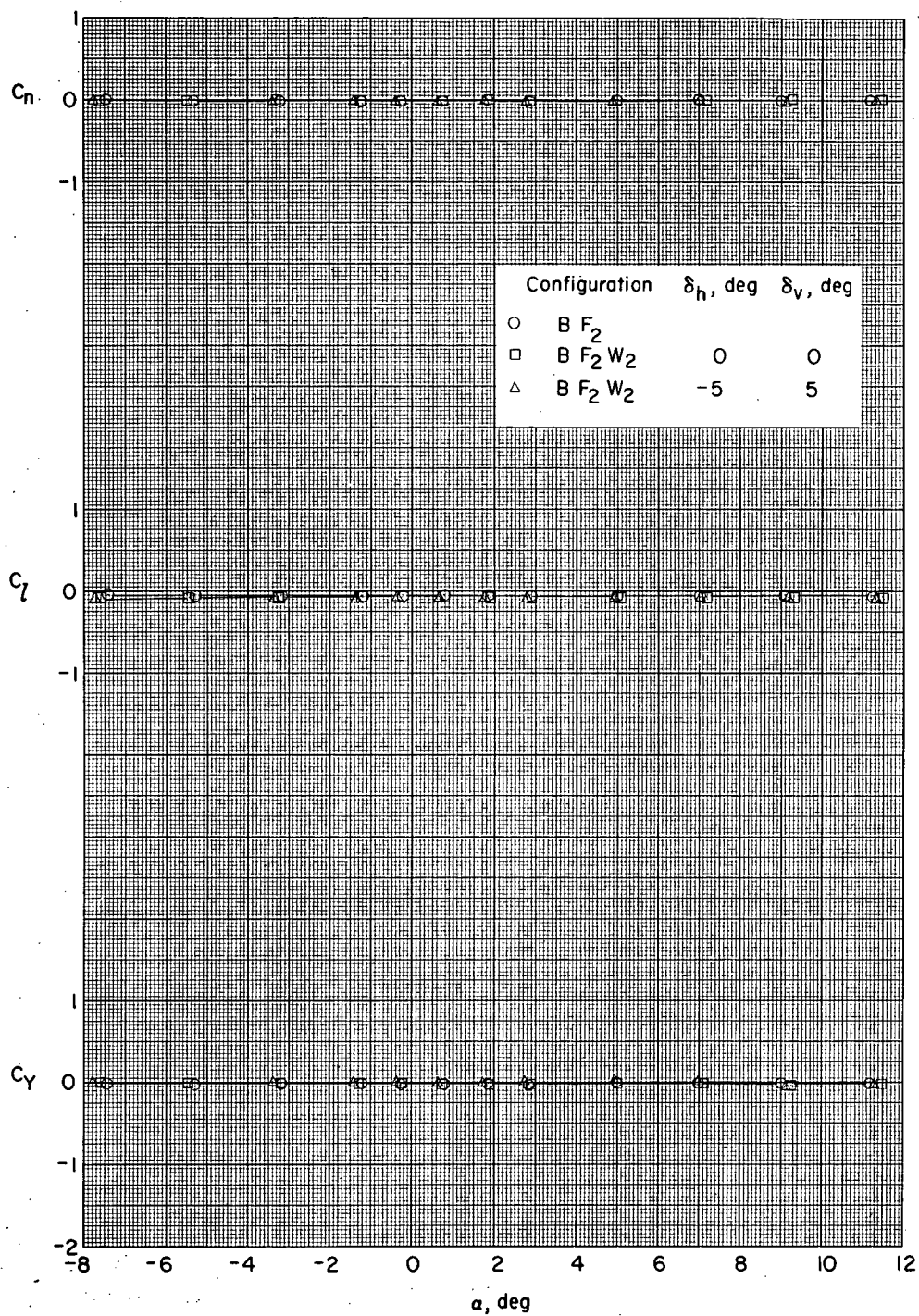
(f) Lateral-directional aerodynamic characteristics. $M = 2.00$; $\phi = 0^\circ$.

Figure 3.- Continued.



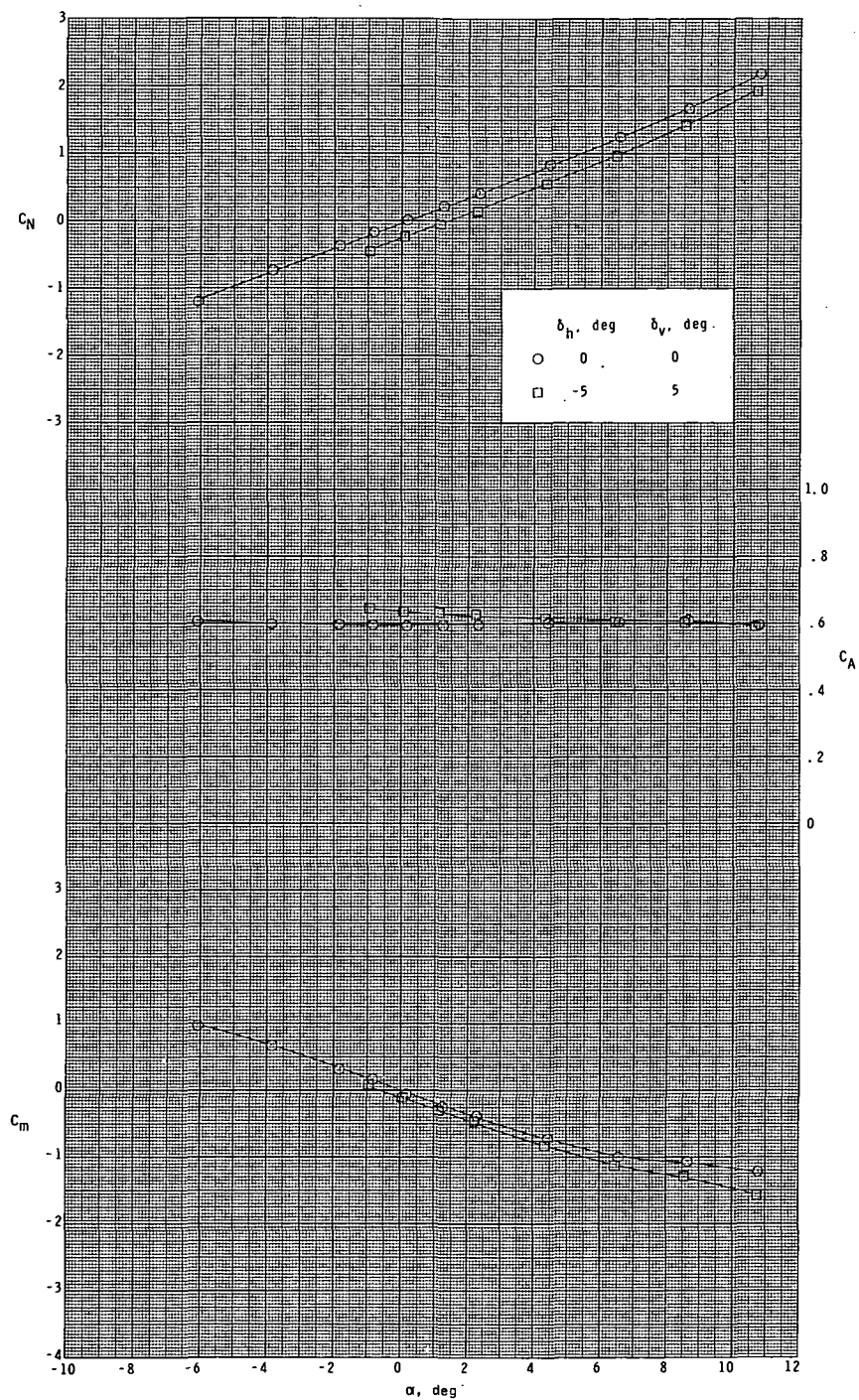
(g) Longitudinal aerodynamic characteristics. $M = 2.00$; $\Phi = 45^\circ$.

Figure 3.- Continued.



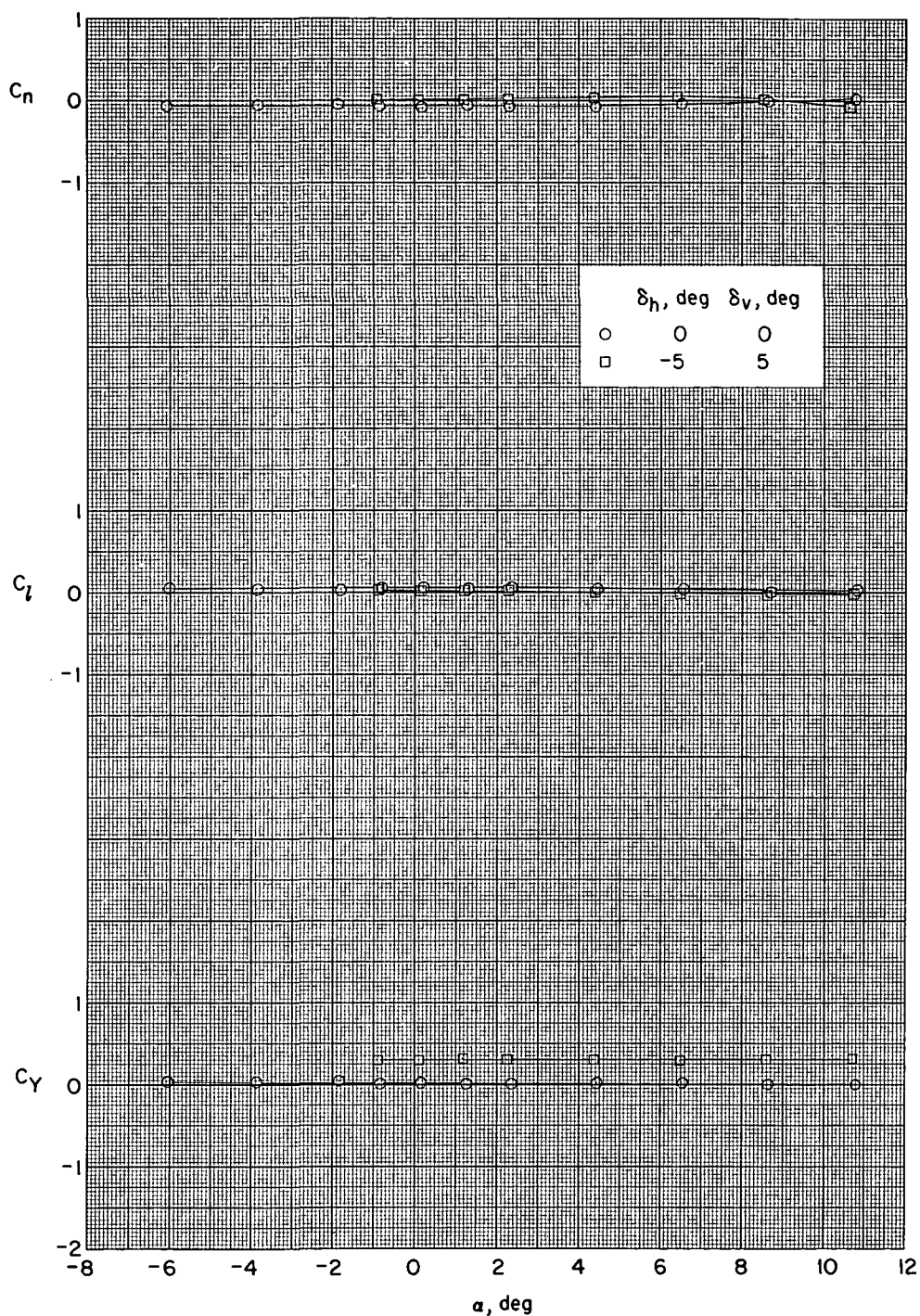
(h) Lateral-directional aerodynamic characteristics. $M = 2.00$; $\phi = 45^\circ$.

Figure 3.- Concluded.



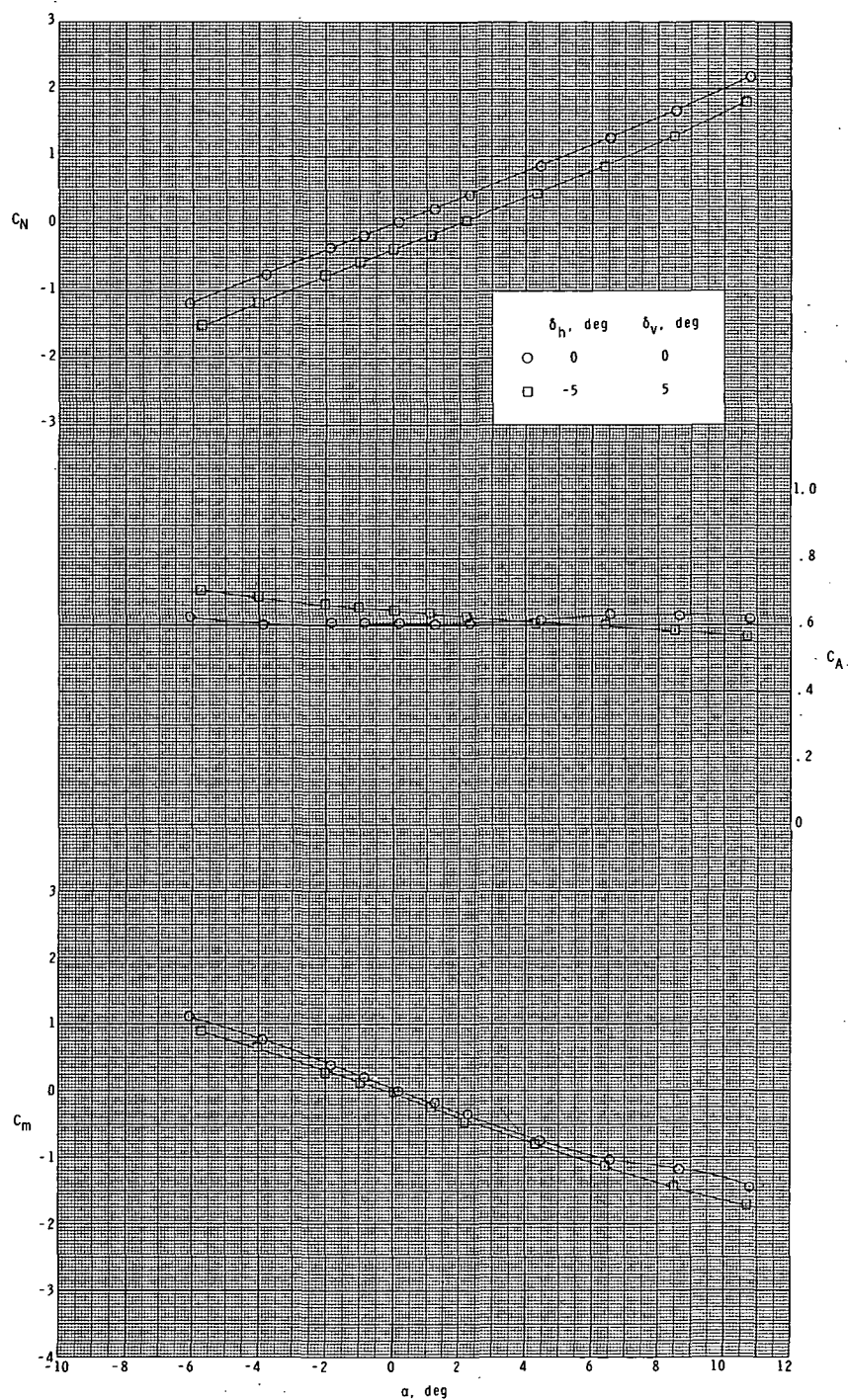
(a) Longitudinal aerodynamic characteristics. $M = 1.60$; $\phi = 0^\circ$.

Figure 4.- Effect of control wing deflection on the model with small control wings and small fins, configuration BF₁W₁.



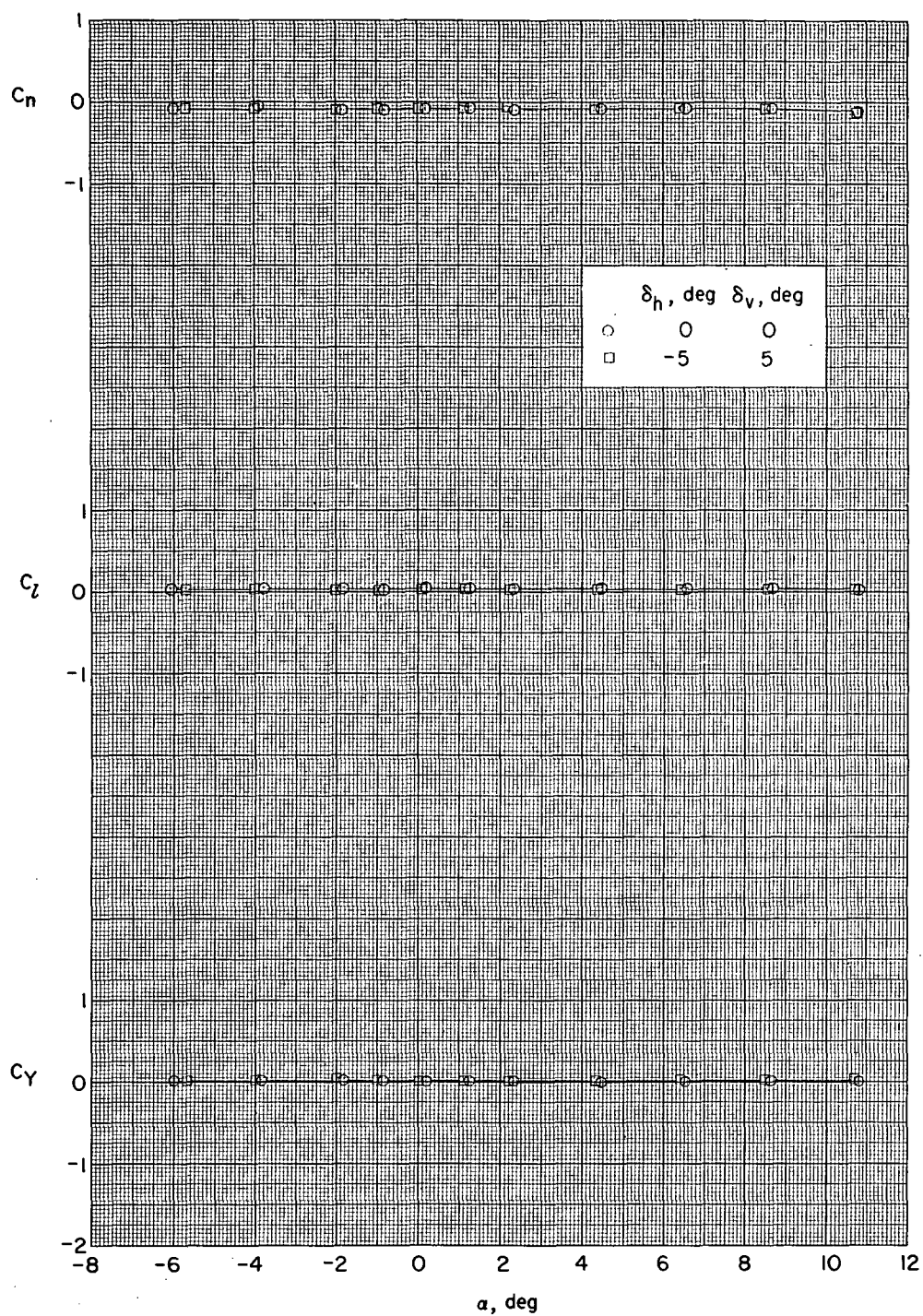
(b) Lateral-directional aerodynamic characteristics. $M = 1.60$; $\phi = 0^\circ$.

Figure 4.- Continued.



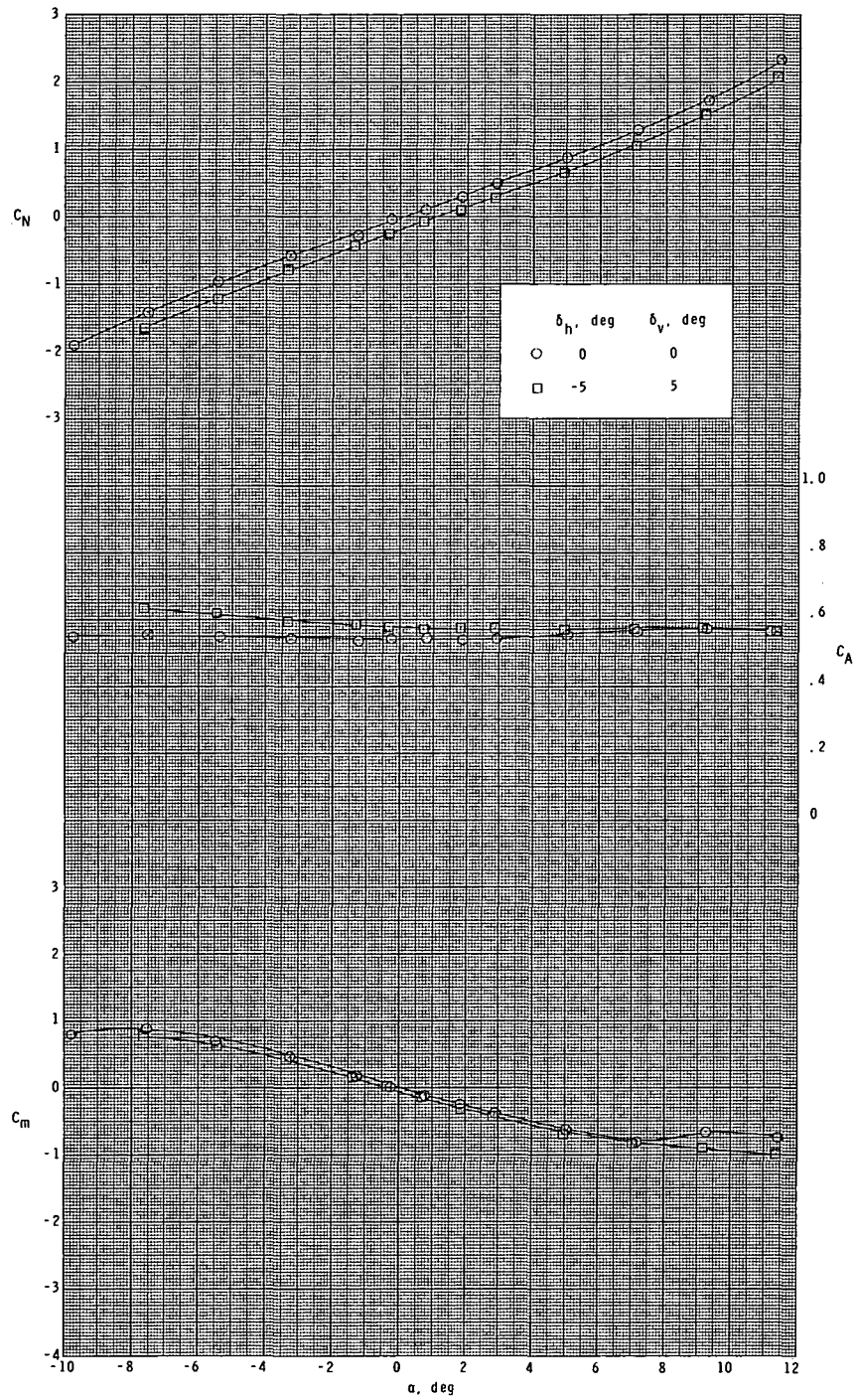
(c) Longitudinal aerodynamic characteristics. $M = 1.60$; $\Phi = 45^\circ$.

Figure 4.- Continued.



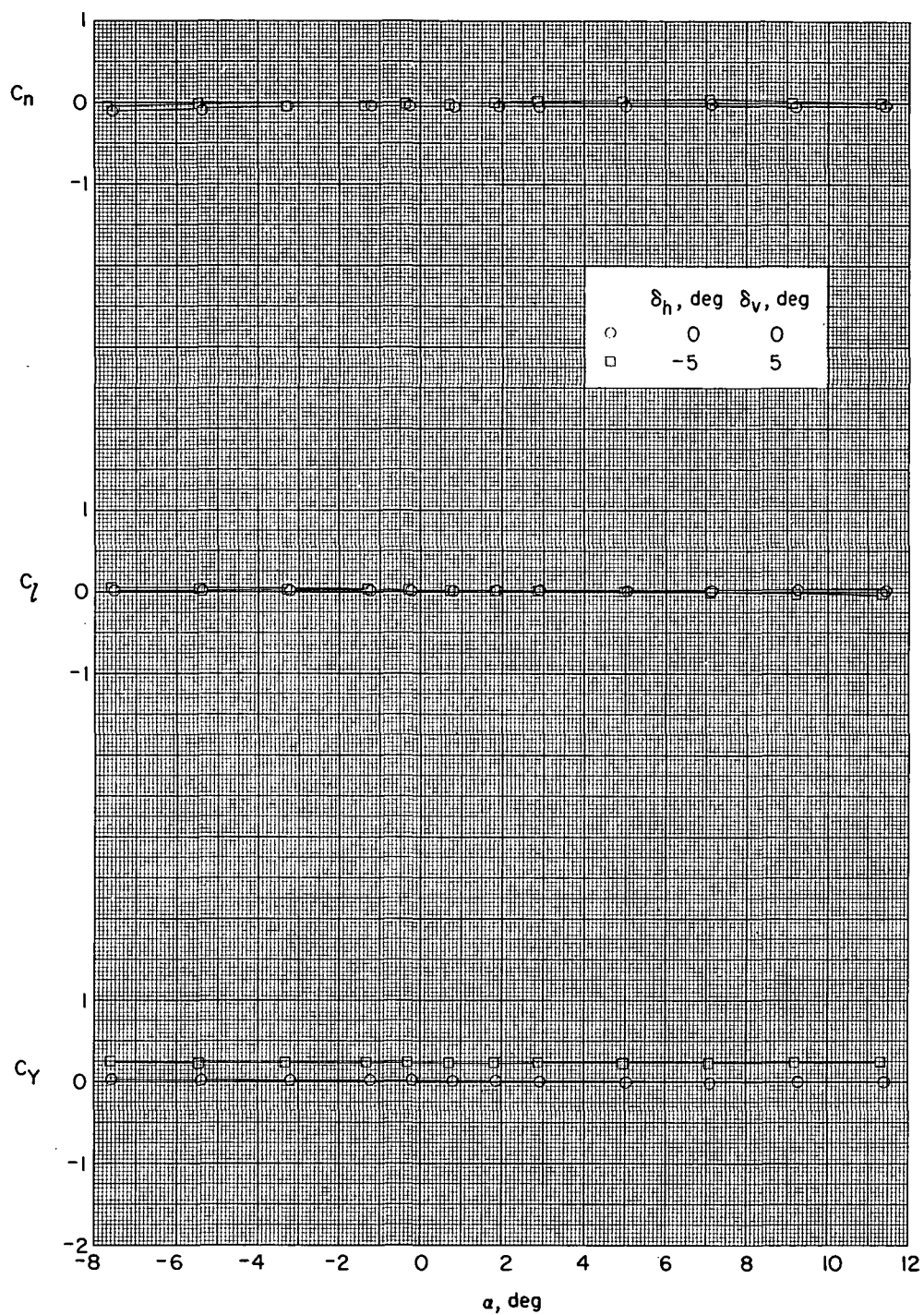
(d) Lateral-directional aerodynamic characteristics. $M = 1.60$; $\phi = 45^\circ$.

Figure 4.- Continued.



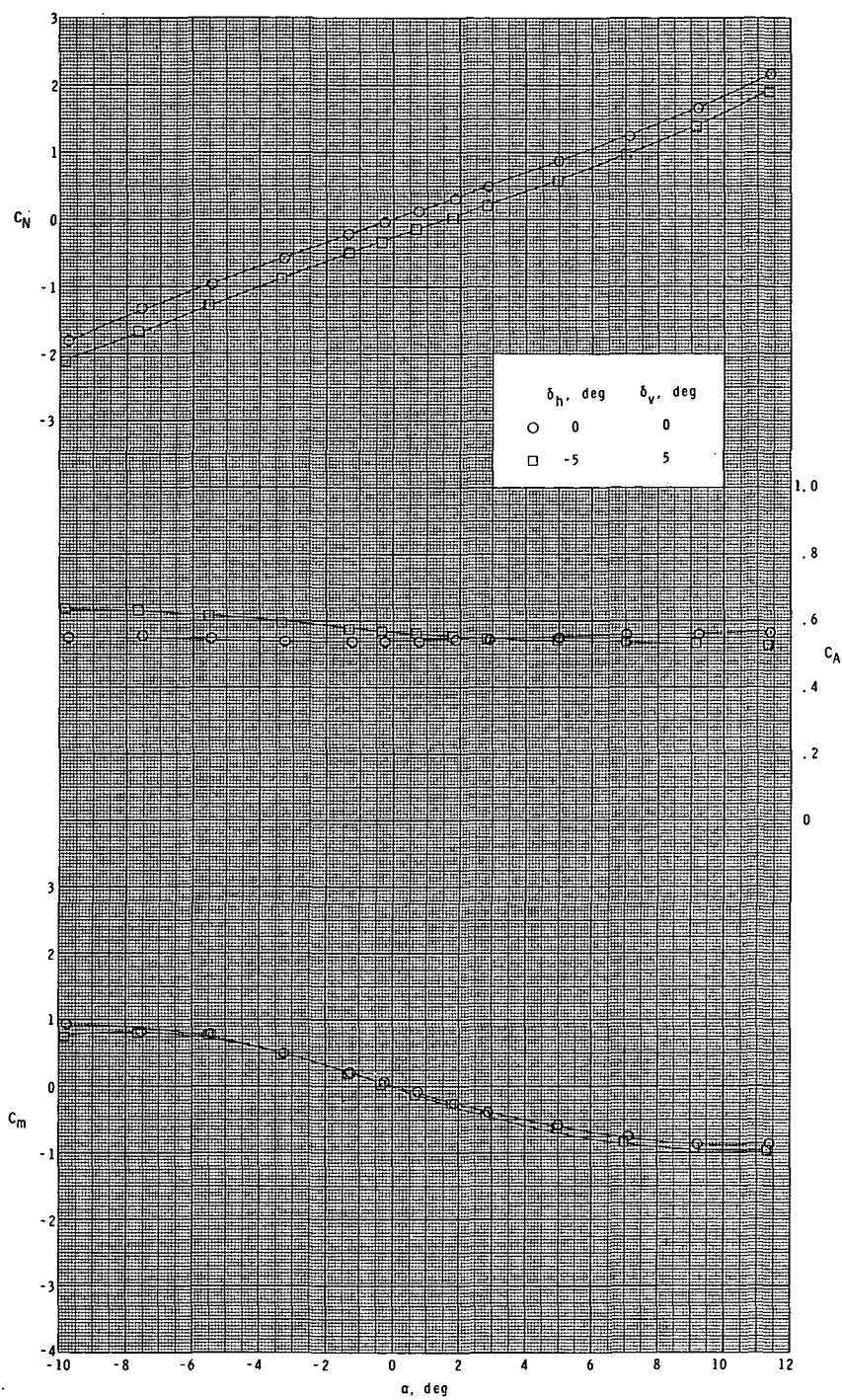
(e) Longitudinal aerodynamic characteristics. $M = 2.00$; $\phi = 0^\circ$.

Figure 4.- Continued.



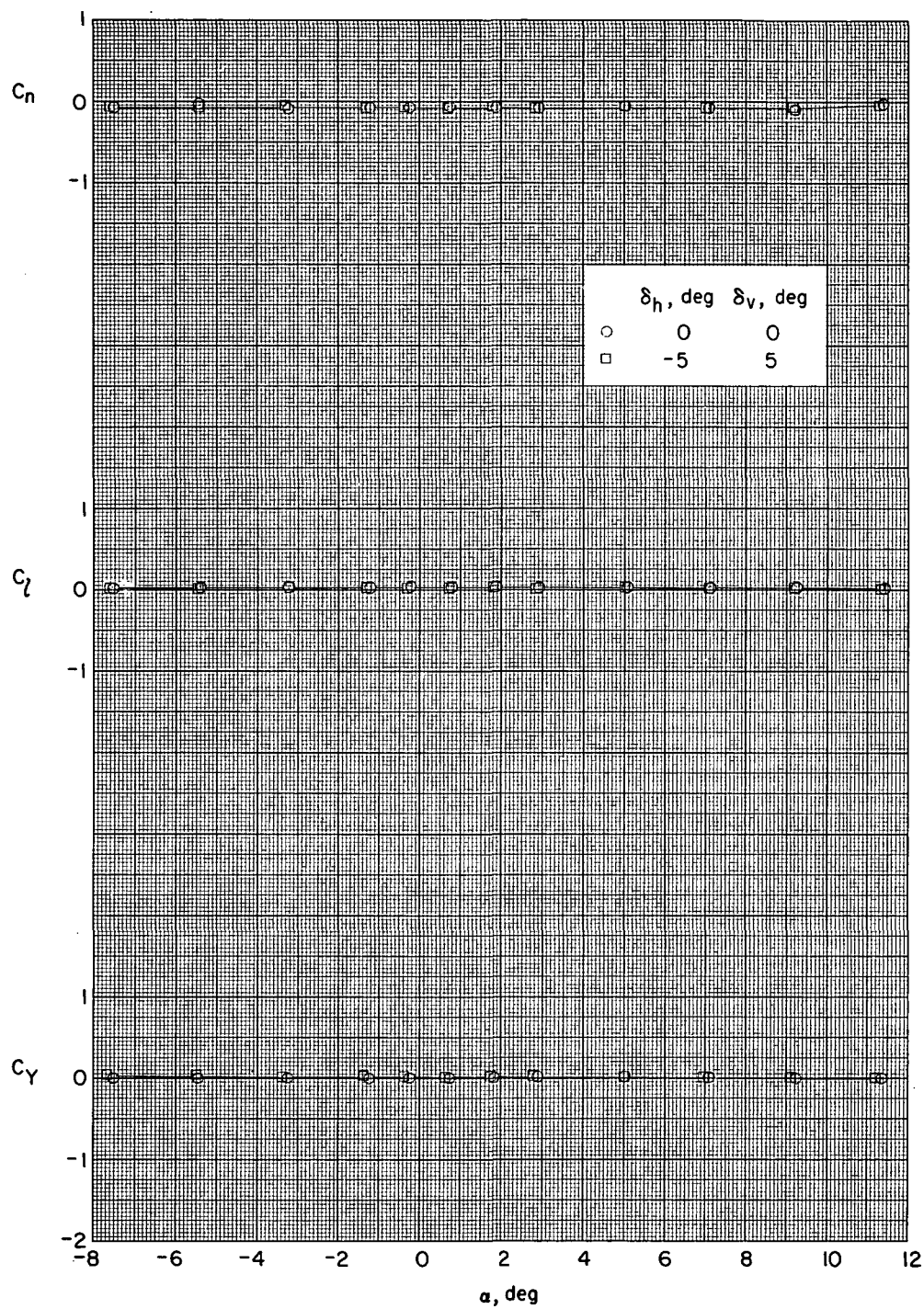
(f) Lateral-directional aerodynamic characteristics. $M = 2.00$; $\phi = 0^\circ$.

Figure 4.- Continued.



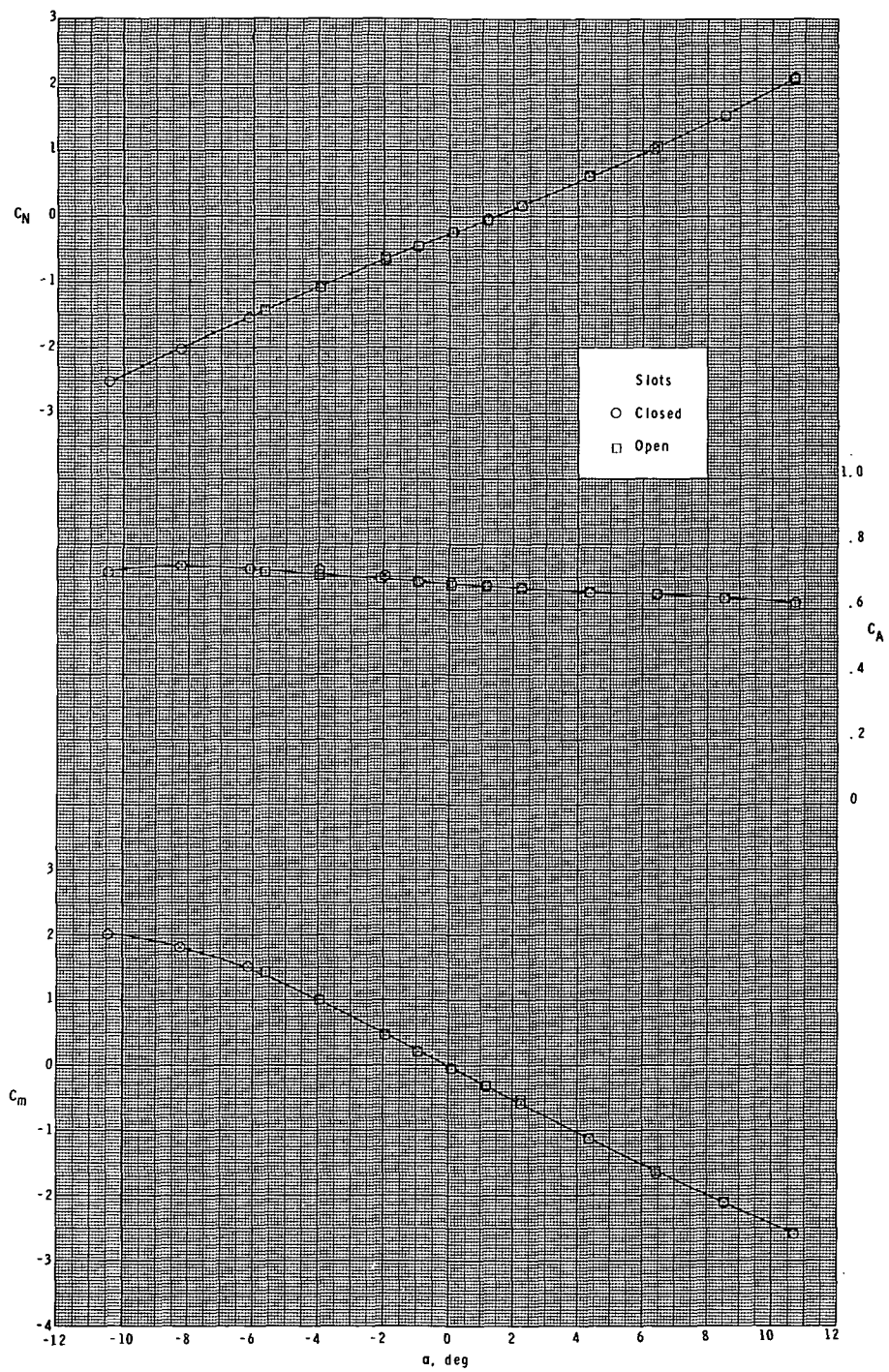
(g) Longitudinal aerodynamic characteristics. $M = 2.00$; $\Phi = 45^\circ$.

Figure 4.- Continued.



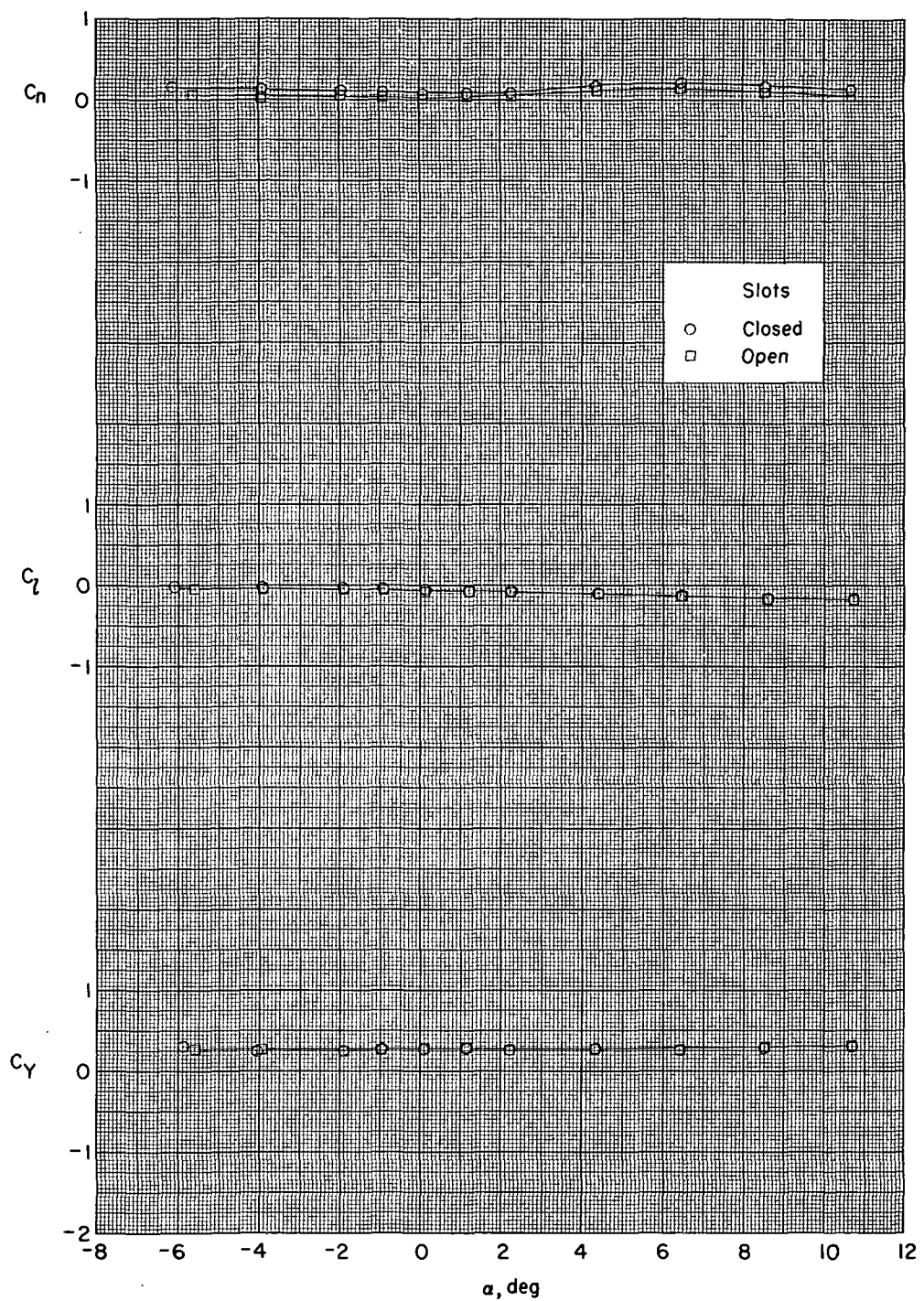
(h) Lateral-directional aerodynamic characteristics. $M = 2.00$; $\Phi = 45^\circ$.

Figure 4.- Concluded.



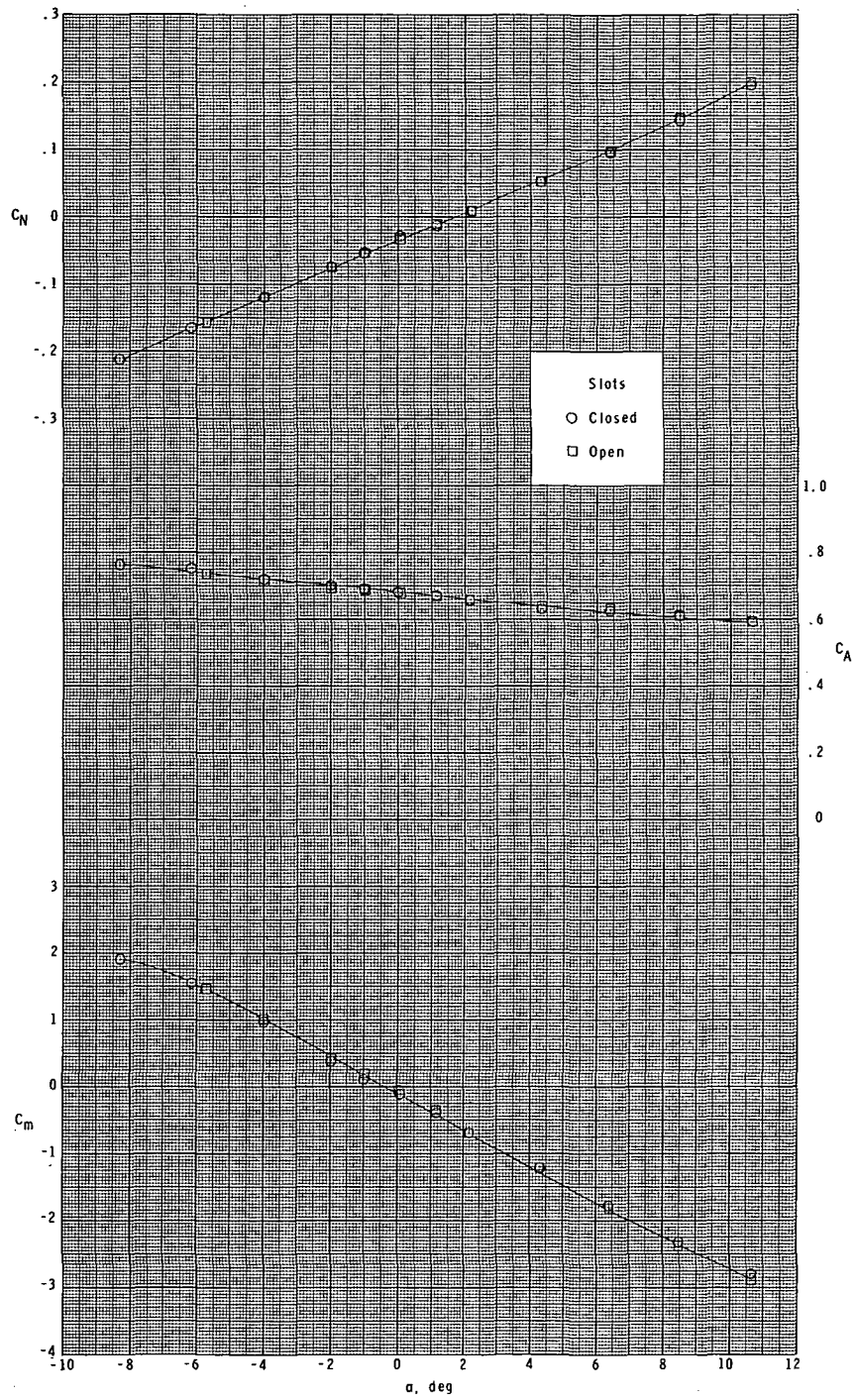
(a) Longitudinal aerodynamic characteristics. $M = 1.60$; $\phi = 0^\circ$.

Figure 5.- Effect of body slots.



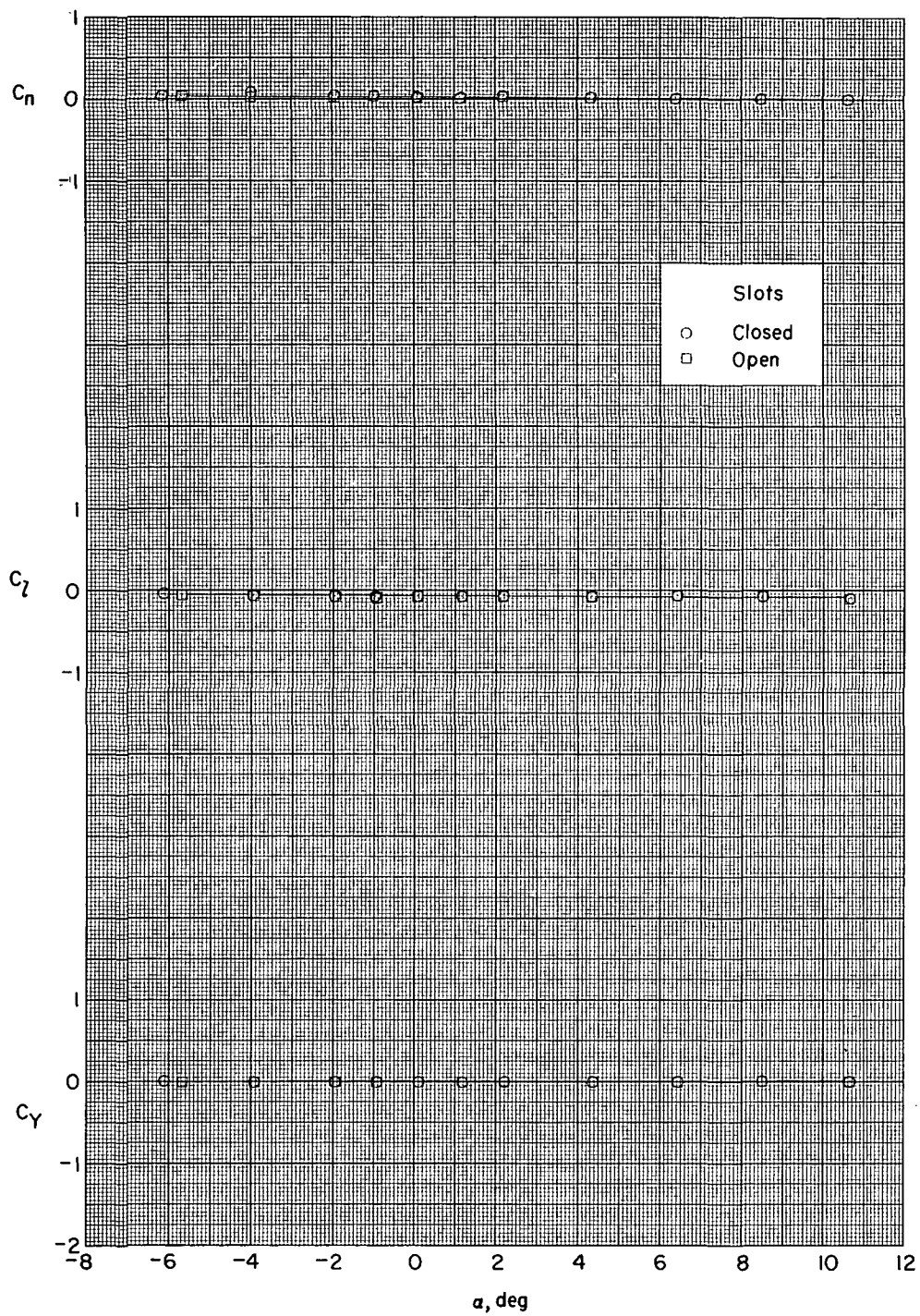
(b) Lateral-directional aerodynamic characteristics. $M = 1.60$; $\phi = 0^\circ$.

Figure 5.- Continued.



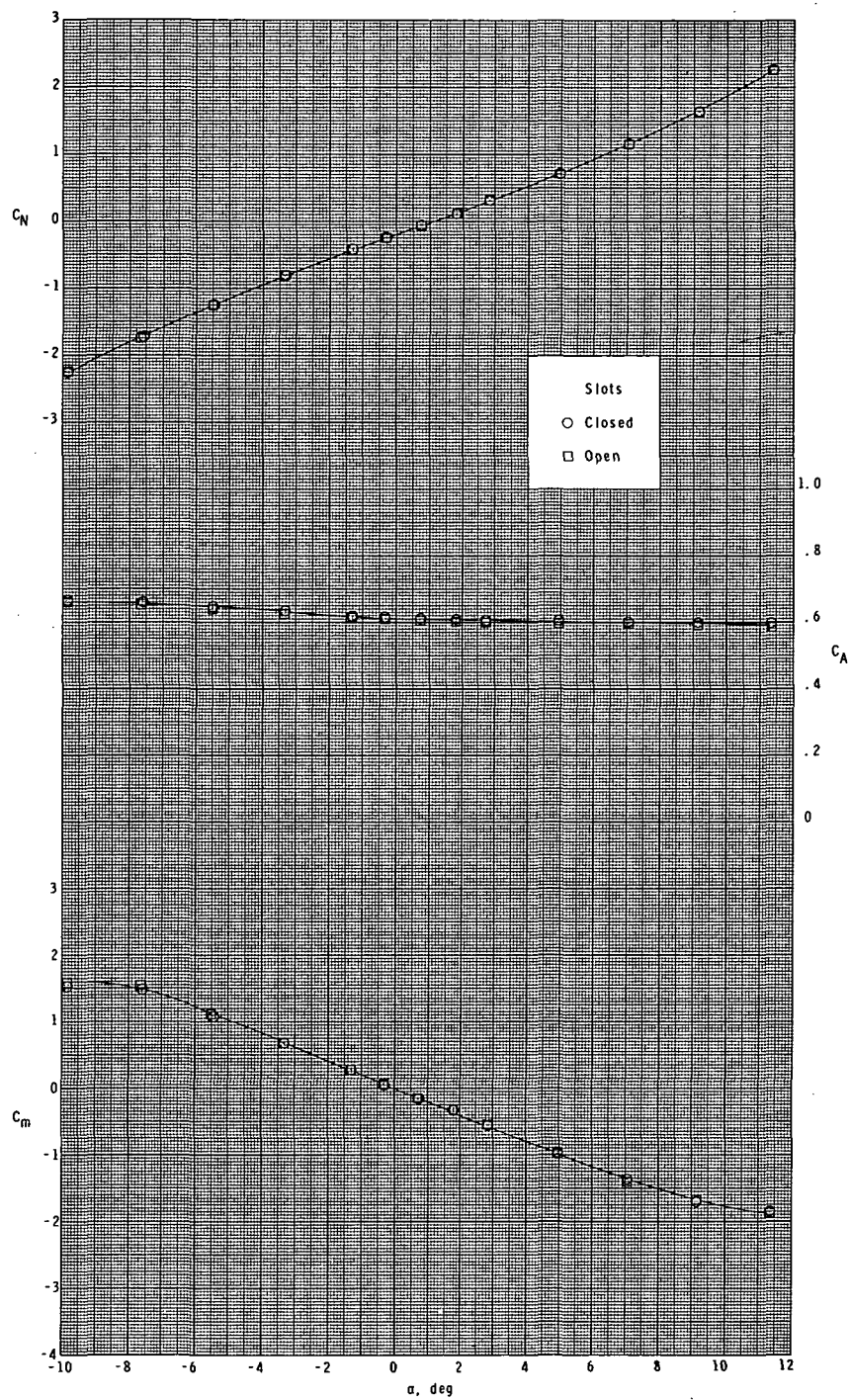
(c) Longitudinal aerodynamic characteristics. $M \approx 1.60$; $\Phi = 45^\circ$.

Figure 5.- Continued.



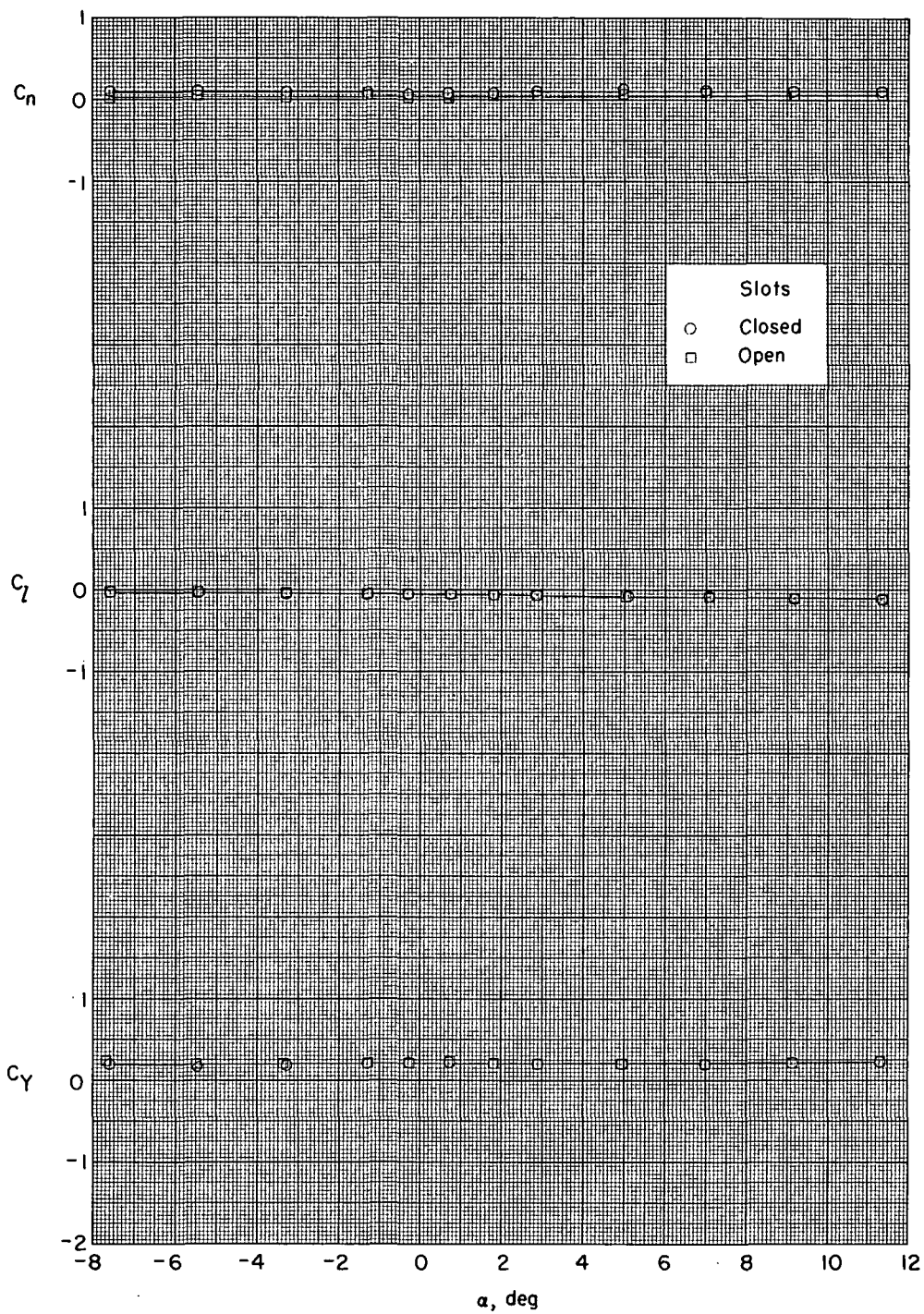
(d) Lateral-directional aerodynamic characteristics. $M = 1.60$; $\phi = 45^\circ$.

Figure 5.- Continued.



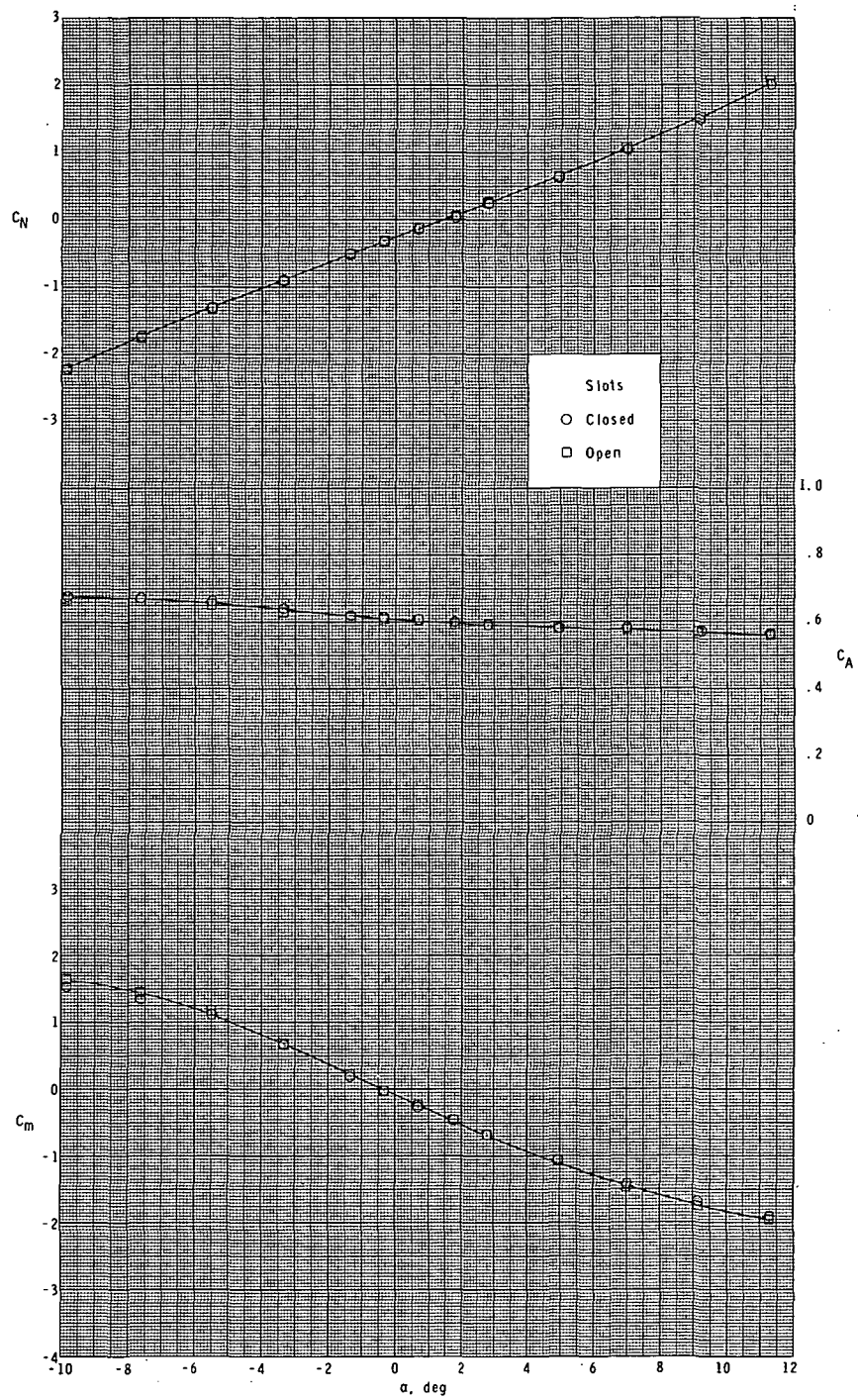
(e) Longitudinal aerodynamic characteristics. $M = 2.00$; $\phi = 0^\circ$.

Figure 5.- Continued.



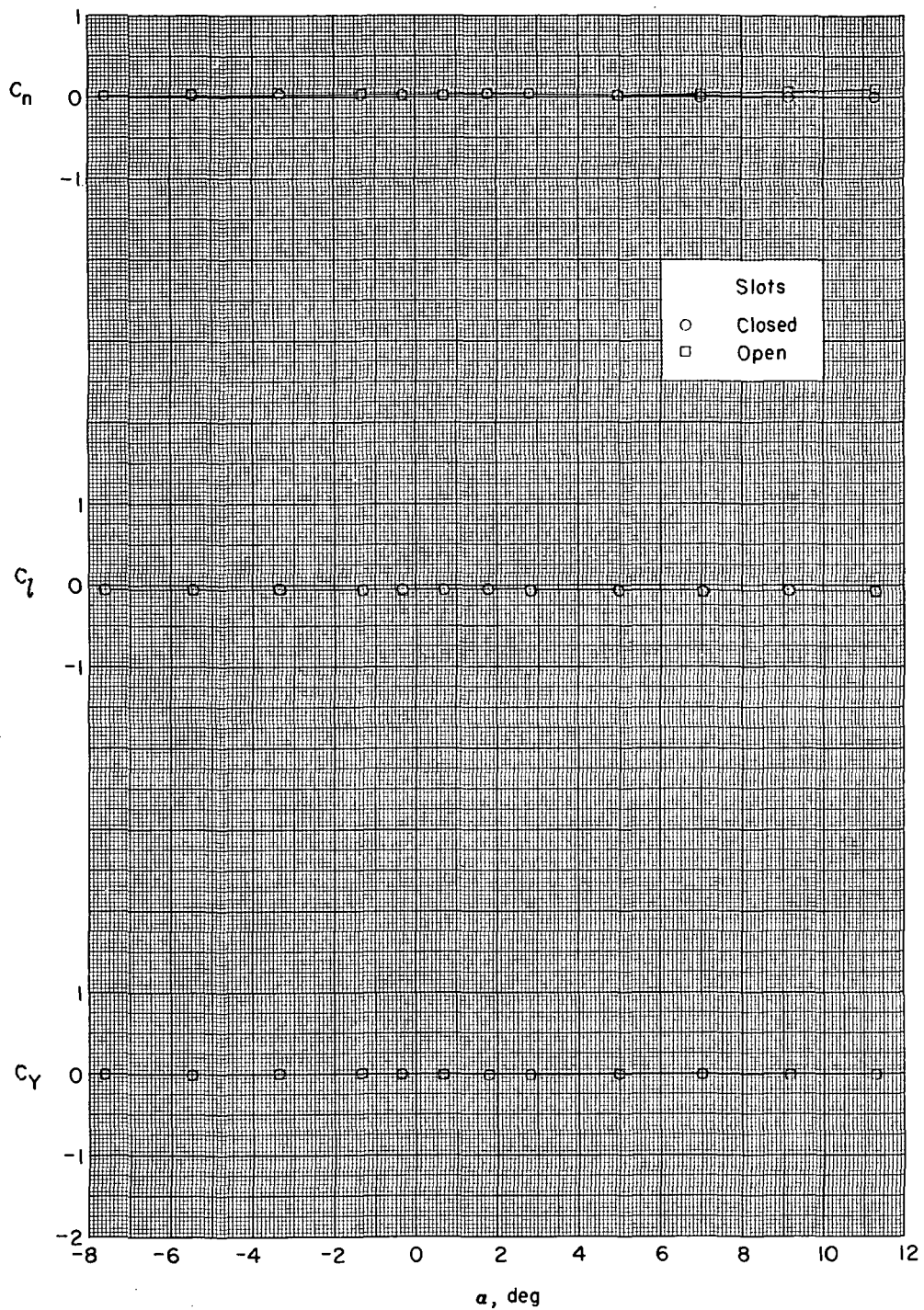
(f) Lateral-directional aerodynamic characteristics. $M = 2.00$; $\phi = 0^\circ$.

Figure 5.- Continued.



(g) Longitudinal aerodynamic characteristics. $M = 2.00$; $\phi = 45^\circ$.

Figure 5.- Continued.



(h) Lateral-directional aerodynamic characteristics. $M = 2.00$; $\phi = 45^\circ$.

Figure 5.- Concluded.

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